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ATOMIC ENERGY ACT—1954

U. S. AIR FORCE

PROJECT RAND

RESEARCH MEMORANDUM

ON THE RISK OF AN ACCIDENTAL OR
UNAUTHORIZED NUCLEAR DETONATION (U)

Fred Charles Iklé

in collaboration with

Gerald J. Aronson and
Albert Madansky

RM-2251

October 15, 1958

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SUMMARY

The unauthorized detonation of a nuclear weapon is possible as a result of technical malfunction, human error, or a more deliberate human act, such as sabotage. It is conceivable that such a detonation will occur within the next decade or so in some weapon system of one of the world's nuclear powers. It can be shown that this risk is not negligible, but it is impossible to say how likely it is.

An unauthorized detonation in a U.S. weapon system which caused civilian damage would certainly be detrimental to United States interests, although the seriousness of the event might vary within wide limits. If the detonation occurred on an overseas base it would probably mean the end of United States base rights, at least in the affected country. It might well cause the fall of friendly governments and rupture Western alliances. An unauthorized detonation in a British weapon system might be almost as detrimental to the United States as if it had occurred within a U.S. weapon system abroad. Conversely, the unauthorized detonation of a nuclear weapon in the Soviet bloc might result in political and military advantages for the United States. It might also have some political repercussions disadvantageous to the United States. Moreover, one should consider the possibility that an unauthorized detonation on either side might lead to an "accidental war." For the next few years, however, this risk seems remote.

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There have been several mishaps with nuclear weapons, such as accidental drops, jettisons, aircraft crashes, and testing errors. A few of these incidents led to the explosion of the HE component, but in almost all cases there was no risk whatsoever of a nuclear detonation, since the nuclear material was not in the weapon, often not even in the vicinity. The incidents provide instructive examples of human errors, engineering deficiencies, and -- to the extent that they became publicized -- also of political attitudes toward nuclear weapon safety.

One should not conclude from these incidents that a significant hazard of a full nuclear detonation has existed in the past. Conversely, we cannot derive much confidence from the fact that no unauthorized detonation has occurred to date. Statistical analysis shows that the past safety record means little for the future, since the number of weapons and the operations involving weapons will increase.

The risk of an unauthorized nuclear detonation and the adequacy of existing safety measures must be evaluated by studying the possible causes of such a detonation: (1) technical malfunction, (2) human errors, and (3) deliberate unauthorized action.

The services and the AEC, with its contractors, maintain several programs to reduce the risk of a full detonation from technical malfunction. We may distinguish three areas of danger from this source. First, there is the possibility of

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random failure of weapon components, especially in the fuzing and firing systems. Theoretical analysis suggests that these failures do not create a significant hazard of a full detonation because there are many independent safing features. Second, there is the risk, during normal operations with nuclear weapons, that external causes (e.g., stray voltages) may lead to a full detonation. Here the problem is to anticipate such causes and to eliminate the risk through design of the weapon or its environment (e.g., handling equipment that will not cause stray voltages). Third, weapons have to be safe from a nuclear detonation in the event that they suffer violence, such as impact or fire in an aircraft crash. This involves primarily the question of "one-point safety," i.e., measures to ensure that an HE explosion will not trigger a nuclear detonation.

In certain unusual situations human errors could lead to a nuclear detonation, especially if several errors occurred in sequence. This danger is negligible, however, in situations where several independent and clearly volitional human actions are needed to cause a detonation.

Finally, in many situations deliberate unauthorized action by one person could cause a full nuclear detonation. Since comparatively little work has been done in this area, the present study gives special attention to it. An individual might intend to cause an unauthorized detonation either because he is a saboteur, or because of an abnormal mental state. Traditional

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security measures are designed to keep saboteurs from atomic weapons. However, neither these security measures nor the ordinary personnel selection procedures can eliminate all individuals who may develop mental disorders that might become dangerous. This is borne out by medical statistics from the services and by case histories of unauthorized acts among military personnel. There are several abnormal mental states that occasionally lead to destructive acts. Most dangerous are the paranoid disorders, whose victims are capable of skillful and secret plotting.

Whatever the actual, but uncertain, risk in the statistical sense of an unauthorized nuclear detonation, the mere fact that the risk exists has serious political consequences. The fear of disaster causes political restrictions in nuclear weapons operations which degrade the defense posture. Since autumn 1957, there has been a persistent Soviet propaganda campaign about the alleged danger of a nuclear accident as a result of the U.S. defense posture. This campaign is important to the extent that it affects allied governments in their decisions about American overseas military operations. It is especially effective where it contributes to existing anxieties about nuclear weapons.

In the British parliament, for example, there was an extended debate about the possible hazards of SAC operations from bases in the United Kingdom. The reaction of the Labor Party foreshadows restrictions that would be imposed on nuclear operations should Labor win the next elections. Even in the

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United States there are serious degradations of the defense posture as a result of the fear of an unauthorized detonation. Current restrictions, for example, affect the readiness of SAC and air defense weapons. Future restrictions may seriously degrade the response capability of missile systems, unless the apparent risk of an unauthorized detonation can be further reduced.

A number of measures can be suggested, both to reduce the actual risk of an unauthorized detonation and to minimize the political consequences of the surmised risk:

(1) The services could gain from a special R and D effort, undertaken by the regular AEC contractors, to evolve new safing principles for future weapons. Greater flexibility in military warhead characteristics may permit novel approaches to weapon safety, which could in turn increase over-all readiness.

(2) The technical feasibility and operational aspects of a "combination lock" (or similar feature) as a warhead safing device should be evaluated. For a few selected weapon systems such a device could permit substantial gains in readiness by replacing more time-consuming operational safeguards and by making higher alert postures politically acceptable.

(3) Missiles for which a short alert time is desirable should be equipped with a control system that makes unauthorized launching impossible, without increasing the vulnerability of the control and command structure to enemy disruption. It is considered feasible to design a system that would eliminate

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delays in launching, by permitting a quicker human response and a higher alert status, instead of introducing the new delays that some tend to associate with safety measures.

(4) Special personnel selection procedures might be developed for a few very critical duties where an unauthorized act by lower rank personnel could immediately cause the release of highly destructive weapons (e.g., the manning of control points in high-alert missile systems). In addition, guidance on the psychiatric aspects of unauthorized destructive acts could be helpful to senior medical officers and certain commanders, who have to make decisions in critical personnel assignments.

The last two suggestions deal with public information aspects:

(5) Local plutonium contamination could result from aircraft crashes or ground transportation accidents involving plutonium weapons. Since the latest information on plutonium tolerance levels is not in the public domain, a political debate on the subject could have harmful effects upon military readiness. The sting could be removed from such a controversy in advance by publicly announcing the present official tolerance levels in reputable scientific journals and presenting the arguments for them.

(6) Some consideration should be given to United States policy in the event that a large unauthorized nuclear detonation should occur. The official reaction should take account of the

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possibility that sabotage may have been involved, or that
sabotage may later cause a second, similar disaster.

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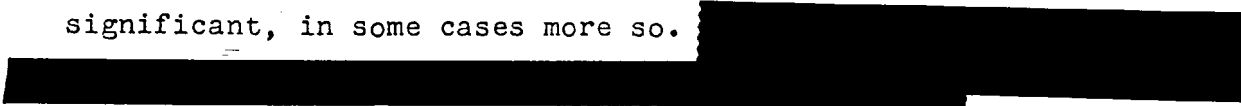
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I. EVALUATION OF THE RISK

Although it seems impossible to estimate the probability of an unauthorized nuclear detonation -- even for U.S. weapon systems alone -- we must nonetheless make an effort to evaluate the risk in order to provide better guidance for policy decisions and operational procedures. No unauthorized nuclear detonation has occurred to date, but a number of minor incidents and non-nuclear accidents which have taken place help one to assess the risk of a nuclear detonation. Besides consulting this empirical material, one can make theoretical studies of the ways in which an unauthorized detonation could conceivably come about.

A. PAST INCIDENTS WITH NUCLEAR WEAPONS¹

The more dramatic incidents involving nuclear weapons all occurred as a result of aircraft accident, jettison, or accidental release from aircraft. But other incidents in connection with weapon modifications or loading operations were perhaps equally significant, in some cases more so.



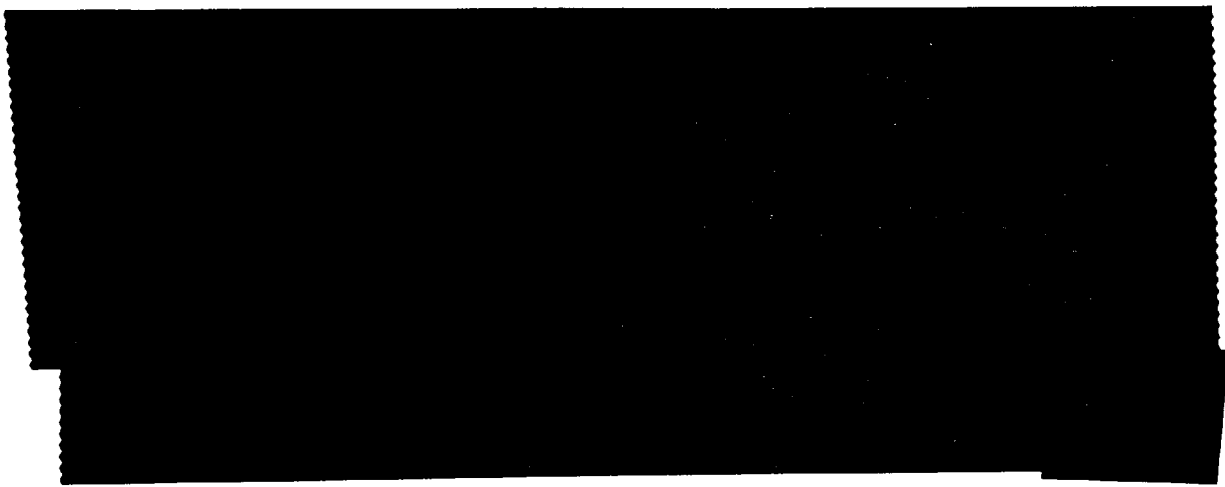
¹Data for several of the incidents discussed here have been provided by the Armed Forces Special Weapons Project, Field Command, especially in the AFSWP Technical Letter 20-3, Accidents and Incidents Involving Special Weapons, 22 July 1957, (~~SECRET~~ ~~RESTRICTED DATA~~). Additional information has been obtained from the Air Force Special Weapons Center, Kirtland AFB, and the Sandia Corporation.

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On another occasion a series of mistakes during a test in the Storage Inspection of an inert Mark 6 weapon led to the firing of the bridge wires. Again, in a live weapon these mistakes would have resulted in an HE explosion. Since the nuclear capsule would normally not have been present, however, a nuclear detonation would not have been possible. Incidents like these indicate the grave importance of avoiding similar combinations of human errors with sealed pit weapons, where the nuclear material is always present and the only margin of safety lies in the firing and fuzing system.

On at least four occasions the bridge wires of inert training weapons were fired as a result of human errors during off-loading from aircraft. Had these been live weapons high-order HE explosions would have occurred; but a nuclear detonation could only have resulted if the nuclear capsules had been inserted. The question arises whether similar combinations of human errors in off-loading sealed pit weapons could lead to a full nuclear detonation. The answer is probably negative for

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those sealed pit weapons that have a trajectory arming switch²; but not all such weapons do have this safety feature.

In addition to incidents involving training weapons there have been a number involving live nuclear weapons. The nuclear capsule, however, usually was not present. To date no incident with a sealed pit weapon has been reported. In some of these cases the public learned that a nuclear weapon was involved, since an explosion of the HE component occurred in or near populated areas or because subsequent salvage operations became publicized. As far as the risk of a nuclear detonation was concerned, the majority of these publicized incidents were quite harmless. They are significant chiefly for their effects on domestic public attitudes and on foreign propaganda about nuclear accidents. No matter how small their physical effects, these occurrences have political importance, and this will be discussed below. There follows here a list of the more dramatic incidents with live nuclear weapons, with notes about the extent to which they were reported to the public. Our list probably includes most of the publicly reported incidents, but fails to cover many that did not attract public attention, especially minor ones occurring in loading operations.

²A switch which normally permits complete arming of the weapon only after it has travelled through part of its trajectory. E.g. the Mark 28 Mod 0 bomb has a differential pressure switch.

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Incident

Reports in Public News Media

(1) Aircraft accident with weapon destruction, April 11, 1950.

A B-29 [REDACTED] crashed in the Manzano Base area (Albuquerque). No HE detonation occurred, but the weapon was broken up and the HE burned in the fire of the crash. [REDACTED]

The New York Times reported the crash, but the question of the involvement of a nuclear weapon was not raised at all.

(2) Aircraft accident with HE detonation.

A B-29 [REDACTED] crash-landed near a base. At first the weapon remained intact, but the fire from the aircraft crash detonated the HE system after about 12 minutes, killing over a dozen people.

This accident and its high fatality were widely reported by the press. However, the public reports suggested that the explosion was due to "demolition bombs." There were no rumors about atomic bombs in the press.

(3) Aircraft accident with HE detonation, 1951.

A B-50 [REDACTED] crashed in Ohio from 7000 ft. The impact must have detonated the HE of the weapon, as there was a crater about 85 ft. in diameter and 45 ft. deep. No civilian damage.

No public reports of a nuclear weapon.

[REDACTED]

No public reports.

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Incident

Reports in Public News Media

No public reports.

(6) Accidental drop with HE
detonation, May 22, 1957.

A [REDACTED] bomb (minus capsule) was accidentally dropped from a B-36 in the desert four miles southeast of Kirtland AFB (Albuquerque). The HE detonated high order, making a crater 30 ft. wide and 13 ft. deep. Field Command, Armed Forces Special Weapons Project performed the cleanup operations.

The incident was noticed by civilians in Albuquerque and briefly discussed on a local television program. (The AFSWP spokesman indicated that the accident did not involve nuclear aspects.) On March 12, 1958, on the occasion of the Florence, S.C. accident, this incident was again mentioned in the Albuquerque Journal, as follows: "A spot near Albuquerque may have been the scene of an A-bomb drop ...similar to the one which occurred in South CarolinaA SAC B-36 plane accidentally released a bomb.... The bomb fell and exploded harmlessly on an uninhabited mesa."

This incident was reported over a month later in the Washington Post, which carried a short item saying that "the Navy dropped a 'disarmed atomic bomb' into the Atlantic." There was also a news conference by the Navy on this incident, and a news release from local Navy authorities. It is likely that the salvage operations, rather than the aircraft accident itself, attracted public attention.

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Incident

Reports in Public News Media

(8) Jettison, July 29, 1957.
Two [REDACTED] weapons had to be
jettisoned in the ocean.

Newspaper reports stated that a crippled C-124 jettisoned "classified cargo" (The New York Times, July 30), or, as the Washington Post (August 1) put it, "a planeload of atom bombs or nuclear-missile warheads was dumped into the Atlantic." According to the Washington Post, "A high governmental source said that the atomic material...had been consigned to U.S. forces in Europe...[and that] the weapons were not armed or primed, and therefore could be considered safe -- for the time being at least." On the other hand, Murray Snyder, Assistant Secretary of Defense, said that "there was no nuclear material in the cargo." On August 18, Radio Moscow broadcast that twenty-five tons of atomic weapons were jettisoned into ninety feet of water off the New Jersey coast on July 29, a statement allegedly based on a report by the Atlantic City correspondent of Pravda.

(9) Aircraft accident with HE detonation, October, 1957.
Fire caused a [REDACTED] on a base to burn with low order detonation. The capsule was in the carrying case and only slightly damaged.

No public reports.

[REDACTED]

No public reports.

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Incident

Reports in Public News Media

(11) Aircraft crash, with no nuclear weapons involved, December 12, 1957.

We list this case merely as an example of an incident where newspaper reports imply that nuclear weapons might have been involved, and the Air Force, for obvious security reasons, is unable to deny this outright.

(12) Aircraft accident with HE detonation, January 31, 1958.

[REDACTED] The capsule was also destroyed, but the contamination was very slight and localized. [REDACTED]

The Los Angeles Times on the following day carried the headline: "Mushroom Cloud Sent Up as 8 Die in B-52. Air Force Refuses to Say Whether Huge Jet Was Carrying Nuclear Weapon." The accompanying story explained that the "huge mushroom cloud" was apparently caused by exploding jet fuel.

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Incident

Reports in Public News Media

(13) Jettison, February 4, 1958.

A B-47 containing a [REDACTED] collided with an F-86 near Hunter AFB. Unable to land, the pilot took the plane over the ocean (near Savannah, Ga.) and jettisoned the weapon. The HE probably did not explode. The Navy has been charged with recovering the weapon.

The New York Times reported that a B-47 had jettisoned a portion of a nuclear weapon, and that the Air Force said "the weapon was in transportable configuration and not capable of nuclear explosion, hence there is no danger of nuclear explosion or radioactivity." A Moscow broadcast on June 7, 1958, referred to this bomb "lying around for four months now," and claimed that the "U.S. command" had evacuated Savannah.

In this case there were, of course, no public reports, since the incident did not involve events that could be seen by the public. It is an interesting example, however, of the kinds of human error which should be guarded against as much as possible by equipment design and proper human engineering.

(15) Accidental drop with HE explosion, March 11, 1958.

A [REDACTED] was accidentally dropped near Florence, S.C. The resulting HE explosion created a crater in a private garden and damaged some houses, without, however, seriously injuring anyone. After take-off the crew noticed (from the monitoring light) that the U-2 lock holding the bomb was not properly closed. The Aircraft Observer went back to the bomb-bay to correct this. While he was in the bomb bay he must have activated the manual release system inadvertently. The falling bomb forced the bomb bay doors open.

This was the most widely publicised incident, because it caused some civilian damage. The newspaper reports varied in detail and accuracy. It was generally stated that the "TNT triggering device exploded." Time (March 24, p. 23) carried a detailed account of the malfunctioning of the bomb lock. Many members of Congress made statements, demanding investigations, prompt restitution, etc.

In the United Kingdom the accident received wide attention and gave new support to the movement for banning patrol flights by SAC from

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Incident

Reports in Public News Media

British bases. Extreme left members of the Labor party during a debate in the House of Commons called for the prohibition of flights with weapons and voiced continued doubts about their safety.

Radio Moscow in broadcasts to Western Europe stated that nine incidents similar to the one at Florence, S.C., had occurred in the United States since 1954. Soviet propaganda exploited this incident to support its demands for a ban on nuclear weapons.

No public reports.



One should not draw hasty inferences from this list about the safety of nuclear weapons handling in the past. These past incidents -- especially the more dramatic ones -- were only indirectly related to the risk of a full nuclear detonation, and it would be entirely unwarranted to conclude from them that a significant hazard has existed in the past. Conversely, we cannot derive much confidence from the fact that no nuclear detonation has occurred in the past. This statistical aspect of risk evaluation will be discussed below.

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The record of past incidents, however, leads to certain useful conclusions. (1) It shows how some minor mishap with a nuclear weapon, or parts of a weapon, may be exploited by the enemy. (2) It indicates the importance of human error as a cause of accidents. (3) The reaction within the services reveals that new safety measures have frequently been instituted as a consequence of an incident. This last point has two exceedingly important implications: (a) It shows that safety engineering, in the field of nuclear weapons as in others, depends to some extent on a learning process. Hence the paramount task is to learn enough from minor incidents to prevent a catastrophic disaster altogether. (b) New safety measures that are instituted after an incident -- especially if they are dictated by political pressures -- may seriously degrade operational readiness. About the latter implication more will be said below.

B. TECHNICAL MALFUNCTION AS A CAUSE OF UNAUTHORIZED DETONATION

Within the limits of this study it is not possible to do justice to the technical aspects of weapon safety. They are mentioned here merely to give the non-technical reader a feeling for the problems involved. There exist a substantial number of reports that deal with technical weapon safety, for which the reader is referred to the Bibliography.

"Technical malfunction" in this context can best be defined as a residual class of events which could lead to an unauthorized nuclear detonation without the direct action of human error.

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Technical malfunction, then, excludes any violation of standard operating procedures or other appropriate technical procedures.

For convenience we may distinguish three types of technical malfunction. First, there are random failures of internal components of a weapon or its related control and test equipment. Such failures would lie primarily in the firing and fuzing system, e.g. shorts, spontaneous squib firings, malfunction of a switch. Component failure usually cannot lead to a full detonation, since all weapons have several safety features in series and strict quality control in manufacture makes failure of even one element extremely unlikely. The probability of simultaneous failure of all the safety features seems to be negligible. (For detailed analyses see the safety studies listed in the Bibliography.)

Second, there are types of malfunction that are not due to the failure of internal components but result from unanticipated external causes of a technical nature which may occur during normal operations. A good example is stray voltages originating in the aircraft or associated equipment. Stray voltages from hoist motors used in weapon loading are known to have led to the firing of low voltage thermal batteries in the Mark 36 Mod 1 and Mark 39 Mod 0 bombs.³ Another, more hypothetical example

³Air Force Special Weapons Center, Report on Inadvertent Firings of MC-640 Thermal Batteries and Associated Safety Implications, SWC-8S-36, 102, April 1958, (SECRET RESTRICTED DATA).

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is the initiation of detonators through a strong radar field.⁴ This type of malfunction can occur even though all the equipment is being handled according to authorized procedures. One might argue that the causes lie essentially in engineering errors. The characteristic of these forms of malfunction is that they can be eliminated readily once they are discovered; but it takes a great deal of ingenuity and intuition to prevent them beforehand. Security against such unanticipated external influences must be sought primarily in the basic design stage.

Third, there is the problem whether violence to a weapon resulting from transportation accidents, plane crash or fire could lead to a significant yield because of some "malfunction." The above list of past incidents shows that the high explosives in nuclear weapons frequently detonate if the weapon is subjected to impact or fire in an accident. If the weapon is "one-point safe" no significant nuclear yield will result from such high explosive detonation (because the high explosive does not detonate symmetrically). "One-point safety" is important for sealed pit weapons, since they do not have the safety feature of the removable nuclear capsule. There exists an extensive

⁴RF energy in the vicinity of the lead wires of an electric detonator can cause firing if the wires act as antennae so that enough energy may build up to be transmitted to the bridge wires and generate a spark. Shielding normally eliminates this hazard. See Melvin C. Hockenbury, "The Reliability of Explosive Components for Guided Missiles," in Proceedings of Joint Military-Industry Symposium on Guided Missile Reliability, Naval Air Missile Test Center, 1957, Vol. I, p. 7.40 (~~CONFIDENTIAL~~).

testing program, in addition to theoretical studies, to determine whether the stockpile weapons are one-point safe.⁵ All sealed pit weapons that are being used operationally by any of the three services are considered to be essentially one-point safe.⁶ However, in some weapon types (both sealed pit and others) detonation of the high explosives may result in plutonium contamination of the area surrounding the scene of the accident. We shall say more about this in connection with the political implications of future nuclear weapons incidents. Apart from plutonium contamination [REDACTED]

[REDACTED] Other hazards, such as the scattering of tritium, are generally of concern only to personnel in the immediate vicinity of the accident.⁷

C. HUMAN ERRORS AS A CAUSE OF UNAUTHORIZED DETONATION

It is well known that a large percentage of all accidents in military operations can be traced to human errors. For example, somewhere between 40 and 65 per cent of the major

⁵The Armed Forces Special Weapons Project "Vulnerability Program." See Bibliography.

⁶In other words, it is expected that there will be no nuclear yield or only a negligible one, although the theoretical calculations are imprecise and the experimental data limited. Cf. Armed Forces Special Weapons Project, Technical Letter 20-2, Hazards Associated With Accidents Involving Special Weapons, (~~SECRET-RESTRICTED DATA~~), 15 August 1957, p. 21.

⁷Cf. ibid., passim.

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aircraft accidents in the U.S. Air Force are due to causes classified either as "pilot error" or as "supervisory and maintenance personnel error."⁸

As mentioned previously, a large number of nuclear weapon incidents in the past have been due to human error. Adequate statistics on human error in handling nuclear weapons are not available, but there is some illustrative evidence. In 390 routine tests of fuzing and firing systems in weapons some ten per cent were duds or failures, about half of which were due to human error.⁹ An analysis of inadvertent firings of the 2.75 in. FFAR air-to-air rocket also brought out that about half were due to human error.¹⁰

In order to appreciate fully the importance of human error as a cause of accidents it must be remembered that human mistakes tend to be under-reported. It is quite natural that a person

⁸Cf. Aircraft Accident Forecast, Directorate of Flight Safety Research, Office of the Inspector General U.S. Air Force, Norton AFB, Calif., Vol. 2, No. 1, January 1958 (~~SECRET~~), pp. 41-55; and The Human Side of Aircraft Accidents, Directorate of Flight Safety Research, Norton AFB, October 1951, p. 3.

⁹H.L. Williams, Our Human Error Problem, Sandia Corporation, Technical Memorandum 137-55-51, July 1955, (~~SECRET RESTRICTED DATA~~).

¹⁰Richard L. Krumm and George L. Murphy, Human Factors in Inadvertent Rocket Firings with Special Emphases on the MB-1 Weapon System, Air Force Special Weapons Center, TR-57-18, August 1957, (~~SECRET RESTRICTED DATA~~). On the basis of similarities between the FFAR rocket and the MB-1, this study concludes that the probability of an inadvertent firing of an MB-1 rocket is somewhat less than 1 per 5000 flights (with rockets). Of the 45 inadvertent FFAR firings studied, 22 could be traced to human factors.

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reporting an accident should prefer to list technical malfunction as the cause, for fear a reported human error might reflect unfavorably on himself or his subordinates. This kind of action not only makes for biased statistics but -- more seriously -- prevents remedial action against many kinds of human error that remain unknown. A great many safety improvements in nuclear weapons have been made only after the discovery that existing design features were a likely source of error. Thus inaccurate reporting is a grave obstacle to progress in human engineering. It has been suggested that the services institute reporting procedures that would overcome some of this tendency to cover-up human errors, for example through anonymity and through special appeals for reports by small groups at the source.¹¹ Reports on human errors must be systematically utilized by the designer for all phases of the stockpile-to-target sequence.¹² The current system of UR's (Unsatisfactory Reports) is not fully adequate to inform the manufacturer or designer about features of the weapons and associated equipment that have led to human errors.

¹¹J.N. Vasilas et al., Human Factors in Near Accidents, Air University, School of Aviation Medicine, Randolph Field, Texas, 1953. This study shows that about twenty times as many incidents were reported through such special procedures as through normal Air Force reporting procedures. The percentage of personnel errors reported rose from 28 to 61 (among 431 reports).

¹²Robert L. Weislogel and Elmer D. West, A Feedback System for Human Error Information, Air Force Special Weapons Center, TR-55-12, August 1955. For further reports on human errors see Bibliography.

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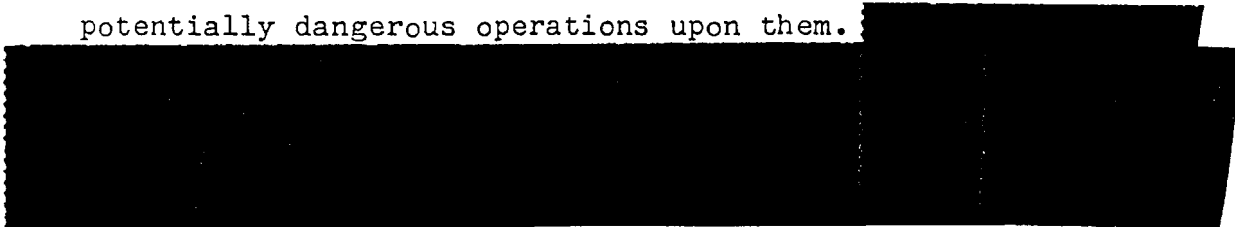
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Above we have mentioned human errors that occurred with training weapons. Some of these error combinations would have led to a full nuclear detonation had the weapons been live and with capsule inserted. The same is true of analogous error combinations if applied to live sealed pit weapons. It must be remembered, however, that the primary purpose of training weapons is to provide practice for inexperienced personnel. Crews are usually more careful when aware that they are handling live weapons, but there is a danger that some careless practices may become habitual in training and be transferred to the handling of war reserve weapons (i.e. live and complete weapons). To prevent this, it has been suggested that training weapons incorporate warning devices, such as small explosive charges, which would alert personnel to the seriousness of their errors.¹³

A matter of serious concern is the occasional shortage of trained weapon specialists in the field, which sometimes makes it necessary to entrust unspecialized personnel with complex tasks on nuclear weapons. Since sealed pit weapons require less maintenance and are simpler to handle than older weapons, it will be easier always to exclude unqualified personnel from potentially dangerous operations upon them.



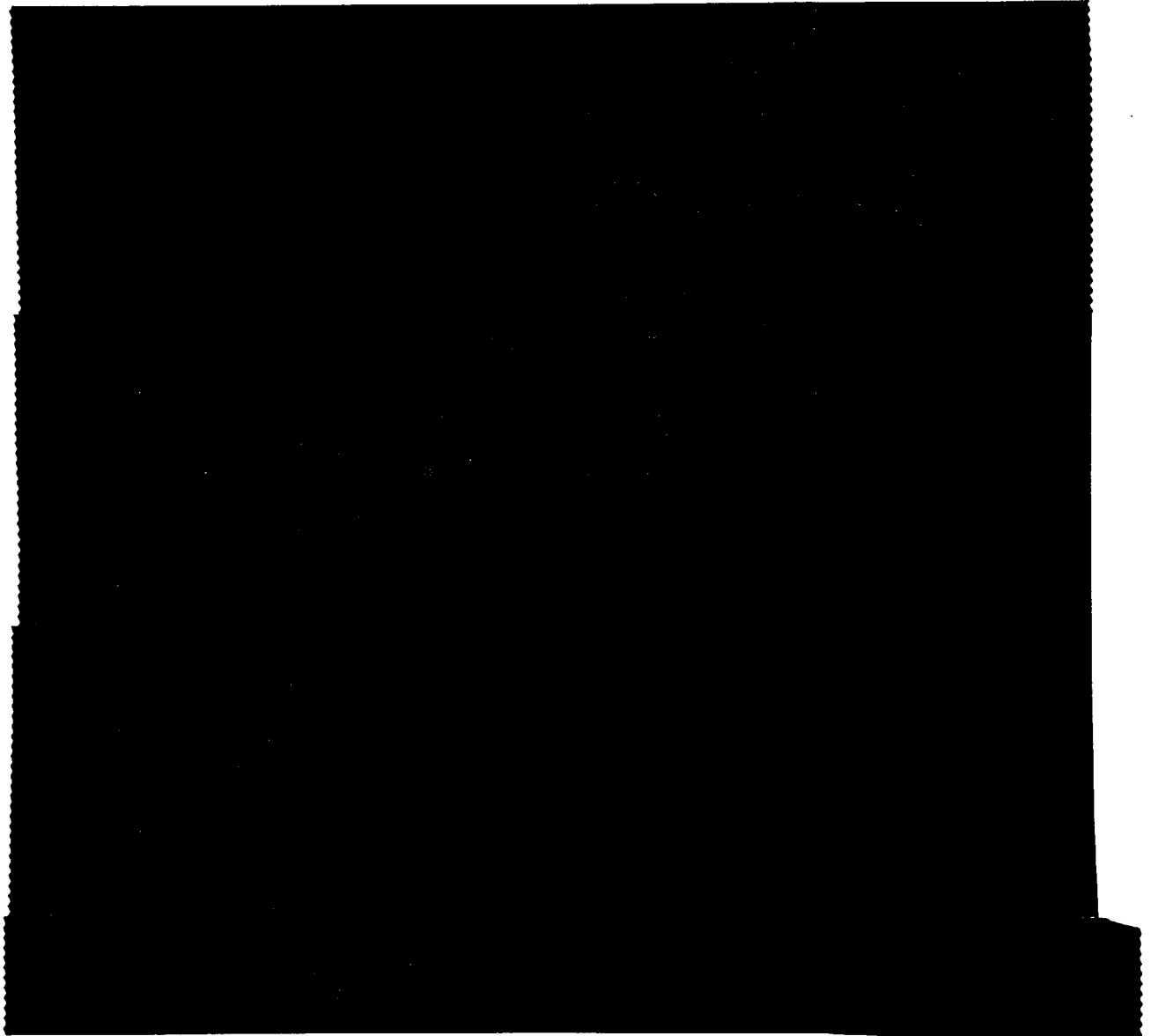
¹³Richard L. Krumm and Robert L. Weislogel, Human Factors in the TM 61-A System, Air Force Special Weapons Center, TR-56-2, March 1956 (~~SECRET RESTRICTED DATA~~), p. 6.

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¹⁴In the weapons with removable capsules, the capsule would have to be inserted and the Arm/Safe Switch armed. In certain configurations of sealed pit weapons, only arming of the high voltage safing switch would be necessary; but additional safety features have been developed that will make it exceedingly unlikely that such an action will be done inadvertently. (Air Force Special Weapons Center, Safety Study of Certain Strategic and Tactical Nuclear Weapons, Addendum, January 1958 (~~SECRET~~ ~~RESTRICTED DATA~~), p. 5.



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The command structure of a high alert posture also produces a situation particularly vulnerable to human error. For either offensive or air-defense missiles a command to fire can and must be executed quickly, and the action is irrevocable. The danger here is that a command may be transmitted erroneously or misunderstood. Examples of such accidents from military history are rare. In the incident of the misunderstood invasion alert in England on September 7, 1940, no irrevocable actions were taken apart from the demolition of a few bridges; it was more a case of excessive alert.¹⁶ Recently, an unofficial account was given of a more serious incident due to human error which occurred during World War II. If this account is accurate, a live torpedo was fired from the U.S. destroyer William D. Porter at the battleship Iowa, when the latter was taking President Roosevelt to the Teheran conference. The Iowa was used as a target for a simulated attack and barely escaped a torpedo

¹⁶The codeword "Cromwell," which meant "invasion imminent," was issued deliberately by Headquarters, Home Forces, in order to bring the forces into a greater state of readiness. Upon this, some Home Guard commanders called out the Home Guard by ringing the church bells, which led to rumors of enemy landings. After this incident, intermediate stages of alert were devised. Cf. Winston S. Churchill, Their Finest Hour (Boston, 1949), p. 312; Basil Collier, The Defense of the United Kingdom, (London: H.M. Stationery Office, 1957) p. 224; and Peter Fleming, Operation Sea Lion (New York, 1957), pp. 280-282. According to Fleming the confusion was due to the fact that some of the poorly-staffed Home Office headquarters or some of the recently recruited officers did not fully recall what the codeword really meant, and assumed the invasion had actually begun.

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fired because someone had forgotten to safe it.¹⁷ This incident is not a case of a misunderstood command; but it has bearing on the risks of a taut alert posture, emphasizing the precarious borderline between practice and real firings. A serious episode that may have involved a deliberate unauthorized act occurred on September 4, 1939, the day after war was declared. The commander of a German U-boat sank the British passenger liner Athenia, in violation of strict orders not to attack unescorted or unarmed ships without warning and inspection for contraband. For this he was severely reprimanded. Possibly he mistook the darkened ship for a cruiser.¹⁸

Accidents as a result of inadvertent or mistaken manipulations (e.g. in weapon assembly, loading, jettison, etc.) can be reduced by designing equipment in such a way that the opportunities for erroneous handling are minimized. Accidents as a result of misunderstood commands, on the other hand, are more difficult to prevent with traditional human engineering methods. They are primarily a function of the operational procedures. Whatever the design and procedural safeguards, however, an accident may nevertheless occur because of failings of the human operators themselves. A considerable amount of research

¹⁷ The account was given by a former lieutenant of the Porter (The New York Times, March 16, 1958).

¹⁸ Anthony Martienssen, Hitler and His Admirals, New York, 1949, pp. 22-23; Vice Admiral F. Ruge, Sea Warfare 1939-1945. A German Viewpoint, London, 1957, pp. 45-46.

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has been done to determine whether some individuals are more accident-prone than others.¹⁹ Except for the identification of rather obviously unsuitable personnel, the results have not been encouraging. More clearcut relations can be demonstrated between the tendency to have accidents and temporary psychological or physiological states, such as fatigue, toxemia, and emotional strain. Studies about the last, especially, suggest some relationships that might not have been expected on common sense grounds. Persons who repeatedly have traffic accidents, for example, have been found to show evidence of poorer social adjustment.²⁰

Psychiatric studies of accidents involving human errors suggest that these errors may be committed as the result of impulsive attempts to resolve certain tensions. While such interpretations are usually ex post facto and hence not useful for segregating those likely to have accidents, they do point out the importance of subconscious factors in the person who commits the error. This leads us over to the question whether actions more deliberate than an ordinary "mistake" could lead

¹⁹Robert L. Thorndike, The Human Factor in Accidents with Special Reference to Aircraft Accidents, USAF School of Aviation Medicine, Randolph Field, Texas, 1951; and Ross A. McFarland, Roland C. Moore, and A. Bertrand Warren, Human Variables in Motor Vehicle Accidents, Harvard School of Public Health, Boston, 1955. Both these studies give an excellent review of the literature. Some of the earlier views on the importance of accident-proneness were due to faulty statistical interpretations.

²⁰Ross McFarland et al., op. cit., pp. 26-27.

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to an unauthorized nuclear detonation. Here is one of the most baffling problems of nuclear weapon safety, and it requires careful examination.

D. DELIBERATE ACTION AS A CAUSE OF UNAUTHORIZED DETONATION

We are here concerned with unauthorized acts that are done more or less deliberately with an intent to cause the detonation of a nuclear weapon. By and large, intentional acts will not be prevented by the safety measures that are effective against human errors, such as the requirement for several independent steps in the arming process, safeguards which prevent inadvertent manipulation (e.g. a seal), and training personnel to maintain safe procedures.

The borderline between an inadvertent mistake and a deliberate unauthorized action is vague. On the one hand, subconscious motivations may contribute to certain apparent mistakes; on the other hand, they may lead to actions that seem to be deliberate. An intent to cause destruction may be perfectly clear to the person who performs a certain act, or it may be concealed from him in his subconscious; it may be persistent and lead to a long-range plot, or it may arise as a fleeting impulse. For some seemingly deliberate acts no motive at all can be discovered.

In what kind of persons and under what circumstances may the intent arise to commit a destructive act? The underlying motive need not differ from the usual motives of common crimes

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of violence, like murder; but if the act of destruction were as extraordinary as the release of a nuclear detonation, the motive would more probably be an outgrowth of an abnormal mental state (such as can be found in some, but not in all crimes of violence). This mental state may be a temporary disturbance, like an epileptic seizure, that interferes with the normal volitional processes, or it may be a more permanent derangement. Usually one can identify a mental disorder as the cause of an abnormal mental state. Among the more or less permanent forms of derangement, those due to paranoia, psychopathy, or impulse disorders are particularly serious in this context. More short-lived dangerous mental states may be caused by psychomotor epilepsy or concealed alcoholism (pathological intoxication). Some temporary mental states are potentially dangerous but are not clearly associated with a mental disorder, for example "fugues"²¹ or undifferentiated strong emotion producing impulsive action (e.g. a sudden fear or panic reaction).

For obvious reasons we do not include here mental disorders that can be readily detected before becoming dangerous. All the disorders and abnormal mental states discussed here can occur in a way that makes advance detection difficult, so that the customary military selection and screening procedures cannot eliminate the risk entirely. These procedures are

²¹A "fugue" is a sudden, temporary disorganization of personality with no identifiable cause. For fuller explanation see p. 142.

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treated in detail below, and a more complete treatment of the psychiatric problem will be found in Appendix I, which is a necessary complement to this section for all those interested in the psychological and psychiatric aspects.

1. Illustrative Examples of Dangerous Mental States and Disorders

The most dangerous disorders are those of the paranoid group. Advance detection is often difficult because persons afflicted with such disorders can act conventionally enough to avoid arousing suspicion. This is illustrated by the histories of paranoid persons who committed spectacular destructive acts. Of the seven attempts on the lives of Presidents of the United States six were committed by such persons. Although family and close friends commented years before the act on the peculiarities and eccentricities of each of the potential assassins, none was so patently ill as to have been hospitalized, and strangers did not observe their lurking illnesses. Such persons may continue to perform difficult jobs efficiently, as in the following case of an Air Force pilot:

A 33 year old Captain began to feel that his new job as Food Service Officer was overwhelming. He became confused, grandiose, inappropriate, and demanding. He felt that his men regarded him, rather than the commanding officer, as their leader and he wrote letters giving orders to his commanding officer. During this period of schizophrenic confusion he logged eight hours on the B-25 with unimpaired proficiency.²²

²²From Charles Sarnoff, Medical Aspects of Flying Motivation -- A Fear-of-Flying Case Book, Randolph AFB, Texas, October, 1957.

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There are two delusional complexes frequently observed in paranoia or paranoid disorders which could bring forth the intent to cause an unauthorized nuclear detonation. One is the desire to seek fame -- even by a purely negative act -- and to immortalize one's name. The other complex is the idea of having a special mission in history. The interval between the hatching of the destructive idea and the actual attempt may last anywhere from a few weeks to several years, and during it these madmen can plan carefully and sometimes shrewdly, watching for an opportunity to carry out their intentions. It is this kind of methodical plotting which is particularly serious for nuclear weapons safety.

More frequent than these paranoid acts are senseless destructive acts committed as a result of impulse disorders or psychopathy. Usually they do not have the scope and magnitude of the paranoid group, but if they involve highly destructive tools they can also cause catastrophe. There are cases where a man has pulled the pin of a hand-grenade in a crowded area "to see what happens"; there are men who have pushed the trigger of a firing mechanism "to find out how it works"; and unqualified personnel have taken up airplanes without authority and usually had to make crash landings. These acts may look like irresponsible horseplay by men who have become too casual about the weapons they handle every day. But familiarity with nuclears may also breed carelessness. Moreover, people with certain impulse disorders may even be tempted by the power of the weapon

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and its potential destructiveness, which gives them a feeling of excitement, adventure, and drama. Pyromaniacs, for example, frequently desire to see tangible evidence of their personal power on a large scale and may plan for months to obtain jobs in hospitals or even in the fire department itself.

Although the temporary mental states that can lead to destructive acts show less deliberateness, there are cases of rather well coordinated destructive acts during states of pathological intoxication. The latter is a rare behavioral disturbance occurring after the ingestion of alcohol, sometimes even a small amount. Its dangerousness is well illustrated by an incident reported to have occurred several years ago. An enlisted man in a state of pathological intoxication returned to his military area, went to an operational storage site, overpowered the guard, and attempted to get access to the nuclear weapons.

Other types of temporary personality disorganization may be precipitated by fatigue, or by a lack or an excess of oxygen, but they may also occur without a physiological stimulus, as in the case of fugues. There is a famous historical example, dating back to 1893, when a British Admiral of undisputed integrity sank his own flag ship through a collision resulting directly from an order given by himself, although he was warned of the impending disaster by the captain of the ship.

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He acknowledged his fault immediately afterwards and went down in the vessel, apparently without any effort to save himself.²³

2. The Effectiveness of Existing Screening Procedures

We have seen that certain abnormal mental states, which need not interfere with occupational duties, may cause a person at some point to commit a highly destructive act. To what extent can such persons be kept from access to nuclear weapons by the existing screening procedures in the Armed Forces?

The first processes involved in the selection of Armed Forces personnel are the preinduction and induction examinations. The former eliminates Selective Service registrants whose destructive propensities have led to a serious criminal record, and also as a rule those who suffer from a serious mental disorder (psychosis) that is readily apparent. By and large, however, the psychiatric examination for both preinduction and induction can eliminate only persons whose mental disorder manifests itself during the short period of examination, and it may well miss less apparent mental disorders, such as an incapsulated paranoia or pyromania. In fact, the psychiatric requirements for the induction examination have been liberalized since World War II, although the other medical standards have remained almost unchanged. Psychoneurosis of any degree is no longer disqualifying if it has not incapacitated the individual

²³Admiral Sir George Tyron (for more details on this case see p. 143).

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in civilian life, and individuals with a history of transient psychotic disorders are now acceptable if they otherwise demonstrate stability.²⁴

The next stage in the selection and screening process consists in the more or less continuous supervision and evaluation of the men by superior officers during basic training and subsequent specialized courses. An individual's mental disorder may show up in the course of his contacts with other men during training and off-duty activities. These processes are moderately effective and about half of all the disability separations for psychiatric disorders are initiated within the first year of service.²⁵

Additional screening occurs in selection for promotion and during officer training. The selection procedures for flying personnel involve particularly thorough medical and psychophysiological examinations. The effectiveness of various

²⁴Induction Experience During Calendar Year 1954," Health of the Army, X, No. 2 (February, 1955), p. 10.

²⁵According to Army statistics for 1954, 50.5 per cent of all disability separations for psychiatric disorders were initiated within less than one year of service (i.e. the hospital admission, which precedes the separation, occurred within the first year of service), and 68.5 per cent within less than two years. (Medical Statistics of the U.S. Army, 1954, Office of the Surgeon General, Department of the Army, Washington, 1956, p. 308.) In the Navy, 45 per cent of the separations for psychotic disorders in 1956 occurred within one year of service, and 60 per cent within two years. (Ninety-Second Annual Report of the Surgeon General of the U.S. Navy, Medical Statistics for 1956, Bureau of Medicine and Surgery, Department of the Navy, Washington, 1957, p. 128.)

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psychiatric screening procedures for flying personnel has been studied in a research program at the Air Force School of Aviation Medicine.²⁶ The main purpose of this program, however, was to improve the quality of flying personnel in general rather than to detect individuals who might have one of the above-mentioned mental disorders.

Psychiatric disorders constitute a leading cause of disability separations, accounting for about one fourth of all the separations for non-battle causes. Two thirds of these psychiatric separations are due to psychotic disorders. About one third of a per cent of all inductees are eventually discharged for psychotic disorders. Many of these cases, of course, have little or no relation to the dangerous mental disturbances discussed above.

Our main point here is that the ordinary screening procedures cannot be relied upon to prevent unauthorized actions entirely. Some mental disorders are latent and therefore remain undetected; others develop so suddenly that the individual may not be removed from dangerous duty in time.

The limitations of existing screening processes are suggested by the number of admissions to medical treatment and of disability separations owing to psychotic disorders. There is a small but not insignificant number of such admissions and

²⁶ S. B. Sells and J. R. Barry, "A Research Program to Develop Psychiatric Selection of Flying Personnel," The Journal of Aviation Medicine, February, 1953, pp. 29-47.

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separations among military personnel who have been in the service for a considerable time and have presumably passed various screening procedures. In 1954, for example, 105 Army officers were admitted to hospital treatment for psychotic disorders, a rate of 0.81 per 1000 at average strength.²⁷ In 1956, 37 Navy and Marine Corps officers, or 0.43 per 1000, were separated or retired from service because of psychotic disorders,²⁸ as were 88, or 0.61 per 1000 Air Force officers. For enlisted men these rates are at least twice as high.

There is some further evidence that several years of service may pass before a psychotic disorder develops or manifests itself so as to lead to a disability separation. The Army statistics (which are probably representative of the other two services) show that one third of all separations owing to psychotic disorders were initiated (by admission to hospital) after two years of service.²⁹

²⁷Medical Statistics of the U.S. Army, pp. 198-199. The rate for 1953 was about the same.

²⁸Ninety-Second Annual Report of the Surgeon General of the U.S. Navy, op. cit., p. 121.

²⁹A study of psychiatric patients at a treatment center for naval personnel found that "contrary to expectations, those persons who have been in the naval service more than 4 years are proportionately just as likely to become psychiatric casualties as those who have been in a short time." James L. Framo and D. H. Riffe, "An Analysis of Psychiatric Case Histories," U.S. Armed Forces Medical Journal, Vol. 6 (1955), pp. 1284-1297.

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Seriously destructive unauthorized acts have been very rare in military service, even in time of war when opportunities were plentiful. If every year one in a thousand officers and two in a thousand enlisted men are admitted to medical treatment for psychotic disorders, it does not follow that there are as many potential authors of a destructive unauthorized act. According to some informed guesses, only five per cent or so of the psychotic disorders diagnosed are dangerous paranoid disorders. In relation to average strength this is not quite one in ten thousand for enlisted men and one in thirty thousand for officers. Some mental disorders, however, lead to an administrative discharge and so do not appear in the medical statistics. Moreover there are paranoid-schizophrenic individuals whose condition may not be recognized at all.

Further selectivity is involved in assigning men to various duties that permit access to nuclear weapons. There are thorough examinations of flying personnel. Other duties that bring Air Force men in close contact with nuclear weapons are the inspection, assembly, testing, maintenance, and repair of such weapons. There are courses in these tasks for specialist airmen and several courses for officers in the nuclear weapons field. Enrolment requires a security clearance (Secret for airmen, and either Secret or Top Secret for officers). An additional prerequisite for airmen is an adequate grade in the Airmen Qualifying Examination, an aptitude test; and for officers there are

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certain educational requirements.³⁰ None of these selection procedures involves psychiatric screening. Presumably the security clearance is designed to eliminate, among other security risks, those individuals who might conceivably commit sabotage from political motives. It is not designed, however, to detect individuals who might do so because of a mental disorder divorced from any political context. Security procedures can eliminate mental cases only if past behavior betrays them in the Statements of Personal History or in records uncovered by the additional investigations associated with clearance.

The last selection process occurs in the field, with the assignment of personnel to duties that give access to nuclear weapons. Those selected usually will have spent considerable time in the service, not only because the responsibility of the job is fully recognized, but also because the necessary training takes time. Hence the commanding officer has an opportunity to select individuals on the basis of their past performance. Nevertheless an officer, who can usually observe a man only on duty, may fail to detect a latent mental disorder that could become dangerous. (Even qualified psychiatrists are sometimes unable after many intensive interviews to discover such latent disorders as an incapsulated paranoia.) Continuous

³⁰U.S. Air Force Training Prospectus, passim.

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contact among men of equal rank, especially in team work and off-duty activities, is sometimes a better basis for detecting a potentially dangerous individual than the keenest scrutiny by superior officers. Many commands encourage informal relations between crew members and the flight surgeon in the interest of flight safety. This principle could even be of value in diagnosing mental disorders.

The following figures will give an idea of the number of people in the Air Force who are directly concerned with nuclear weapons. Roughly 6000 flight officers are assigned to nuclear weapons missions and have received special training. The total number of SAC and TAC flying personnel is about 11,000, the majority of whom have received some field training with nuclear weapons. In addition, there are the units involved in handling, testing, and maintenance of nuclear weapons, whose authorized strength for 1958 is: 1,238 officers, 12,602 airmen, and 2,141 civilians, a total of some 16,000 people (of whom 4,329 are performing security duties).

3. The Effectiveness of Existing Safety Measures

In addition to personnel screening there are important safety measures for preventing deliberate, unauthorized actions that could lead to the detonation of a nuclear weapon. These take the form of operational control of weapons and built-in technical safeguards. They can be divided into four categories:

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a. Restricted Access to Weapons and Limited Opportunities for Full Detonation. Measures of this kind apply mainly to the transport and storage phases of the stockpile-to-target sequence. Restricted access to weapons is, from a safety point of view, the necessary complement of personnel selection. It must be proof against violence or deception if it is to prevent incidents like the one reported above, where the guard of a storage site was overpowered by a person in a state of pathological intoxication.

One of the most effective safety measures in the transport and storage of a weapon is the removal and separate control of a vital part that cannot be replaced through unauthorized action. Where a weapon has a removable nuclear capsule this object can be readily achieved. For the sealed pit weapons there are suggestions that a vital component remain separate during transport and storage. For shipboard storage of certain weapon types the Navy favors removable batteries.³¹ However, the kind of disassembly that removes a component from the fuzing and firing system rather than from the nuclear system may not be safe against well-planned unauthorized action.³² Moreover, it may introduce new hazards because of increased maintenance.

³¹Armed Forces Special Weapons Project, A Study on Advantages and Disadvantages of High Voltage Power Supply Removability Provisions in Atomic Weapons (U), FC/12570423, December 1957, (Secret Restricted Data).

³²The object of removing vital parts is, of course, to protect against technical as well as human causes of unauthorized detonations.

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Certain safeguards in the fuzing and firing systems are designed to limit the possibility of a full detonation to the kind of environment for which the weapon is intended. Thus, part of the arming of a bomb is accomplished by its release from the aircraft and fall through the trajectory. Arming of those bombs which have a Differential Pressure Switch, instead of a barometric switch, depends on an environment which normally occurs only in the fall through a trajectory. Arming of the Matador-B (TM 61-B with XW-28 warhead) requires acceleration plus certain signals from the ATRAN navigation system that indicate proper guidance and approach to target. The MB-1 (XW-25/Genie) has a safety switch designed to prevent the firing of its rocket while the aircraft's weight is on the wheels.

With one exception, however, the technical safeguards that depend on a special environment could be overcome, at least in theory, by someone who knew the workings of the fuzing and firing mechanism. The exception is the acceleration switch scheduled for the later IRBM's and the ICBM's, which ensures safety as long as the missile is not fired. It will be sealed inside the warhead, unlike the other safety devices which are in separate units outside the weapon casing. It will be impossible to tamper with or bypass this switch except by operations so long and complicated that they could hardly be concealed. They could probably not be carried out by one person. The switch will close only if the warhead receives a certain acceleration or deceleration.

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b. Devices Against Inadvertent Arming. The safeguards which depend on the special environmental influences that follow launching or bomb-drop provide security only up to the point where the missile is launched or the bomb is dropped. There are other safeguards, however, which will prevent a full nuclear detonation if a missile is fired or a bomb dropped accidentally. The activation of a weapon so equipped requires a separate human action, such as arming an arm/safe switch. This kind of device makes it very unlikely that an accidental bomb drop or missile firing will lead to a full detonation. (See below, Section E.) Among weapons which require deliberate arming are Nike-Hercules and Rascal. Special features that make the arming action unmistakable, such as a warning signal or a seal that must be broken,³³ will tend to prevent arming as a result of human error. To some extent these features will be effective against actions of the kind that might occur during one of the before-mentioned temporary mental disturbances (owing to anoxia, psychomotor epilepsy, or a fugue). In this connection a device which positively discourages the unauthorized action, such as a seal, is probably more effective than a warning signal. The latter may remain unnoticed precisely because of the mental disturbance.³⁴

³³Such a seal has been recommended for a number of weapon systems by the Air Force Special Weapons Center (Safety Study of Certain Strategic and Tactical Nuclear Warheads, Addendum, January 1958, [Secret-Restricted Data], p. 18).

³⁴See cases of fugues discussed in Appendix I, pp. 142-145.

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c. Supervision of Personnel. An attempt by an individual to cause an unauthorized detonation may be detected and prevented in time if there is always more than one person present with the weapon. But there are two uncertainties. First, the people present may not notice an unauthorized act, especially if they are preoccupied by an emergency (e.g., jettison). Indeed the act may be so brief and inconspicuous that several watchers miss it. Second, a person determined to commit an unauthorized act may overpower or incapacitate those who oppose him. All the same, the presence of more than one person seems to decrease substantially the opportunities for an unauthorized act. Unfortunately there are some weapon systems which do not permit the continuous presence of more than one person, for example a nuclear weapon in a fighter aircraft when aloft.

d. A Technical Requirement for Action by More Than One Person. The most definitive measure against the detonation of a nuclear weapon through an unauthorized act is a technical feature that makes it impossible for one person alone to cause a detonation. At present some configurations of strategic bombs require action by more than one member of the crew for a drop to result in a full detonation, while others do not.

Discrimination is needed to decide whether a given requirement for joint action is a real safeguard against unauthorized acts. Some of the requirements for the action of more than one person in the detonation of nuclear weapons are merely procedural

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and are not imposed by technical considerations. They could be circumvented by a single determined person.

4. Summary

Individuals with access to nuclear weapons have passed through a number of selective processes tending to eliminate persons who are politically or psychologically unreliable. The selection procedures, however, cannot screen out all those individuals who, at some future time, might commit a destructive act because of a mental disorder. Hence, it becomes necessary to institute operational policies and technical devices that reduce the opportunities for causing an unauthorized nuclear detonation. Supervision of the persons who handle or control nuclear weapons will provide some additional safety against unauthorized acts, but the most effective safeguards are technical devices that make it necessary for more than one person to participate in the detonation of a nuclear weapon. Few satisfactory devices of this kind now exist. They may not be feasible in all weapon contexts. (See also below, Chap. IV.)

An evaluation of the likelihood of a nuclear detonation as a result of an unauthorized act would involve several estimates. First, one would have to estimate the number of individuals with access to nuclear weapons who might have a dangerous mental disorder. It would be a small number, our tentative estimates suggest. In addition, one would have to gauge the probability that such an individual would in fact proceed to carry out the

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actions that could lead to the detonation of a nuclear weapon. Then one would have to estimate the probability that his attempt would be successful. The two last factors must necessarily remain vague. The cases discussed in Appendix I do no more than provide material illustrative of mental disorders that led to highly destructive acts.

E. STATISTICAL EVALUATION

1. Implications of the Fact that No Unauthorized Detonations Have So Far Occurred

The usual way of estimating the probability of an accident in a given situation is to rely on observations of past accidents. This approach is used in the Air Force, for example, by the Directorate of Flight Safety Research to estimate the probability per flying hour of an aircraft accident. In cases of newly introduced aircraft types for which there are no accident statistics, past experience of similar types is used by analogy.³⁵

Such an approach is not possible in a field where there is no record of past accidents. After more than a decade of handling nuclear weapons, no unauthorized detonation has occurred. Furthermore, one cannot find a satisfactory analogy

³⁵Aircraft Accident Forecast, pp. 149-154. These forecasts, however, do not simply assume that the future accident rate will be the same as the past observed one. The concept of learning curves is employed to allow for the fact that the accident frequency of a new type aircraft usually follows a definite trend.

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to the complicated chain of events that would have to precede an unauthorized nuclear detonation. (There are, as we shall see later, analogies for component events.) Hence we are left with the banal observation that zero accidents³⁶ have occurred. On this basis the maximum likelihood estimate of the probability of an accident in any future exposure turns out to be zero. Obviously we cannot rest content with this finding.

It is of great importance to know how much credence one should give to the proposition that there will be no unauthorized detonation in the future; because if the credence is low, it would seem worthwhile to spend more on certain promising additional safeguards, and conversely, if it is high, one may wish to discontinue some existing safety measures that are particularly detrimental to the defense posture. How confident can we be that there will be no accident in the future, given the fact that we have observed zero accidents in the past? We can provide statistical confidence intervals for the probability of no accident in a given exposure to the risk of accident. The degree of exposure is measured by the number of "opportunities" for the causation of an accident,³⁷ such as the number of weapons, or, more roughly, the number of weapon-months (discounting, perhaps, the months of completely inert stockpile storage).

³⁶For brevity we use the word "accident" to mean an accidental or unauthorized detonation of a nuclear weapon.

³⁷Our "opportunities" correspond to trials in games of chance.

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Table 1, using binomial confidence limits, gives the lower 95 per cent confidence limit on the probability of zero accidents, given different numbers of past and future opportunities.³⁸ We can see that this lower confidence limit does not lend much strength to the proposition that there will be no accident in the future, except where the number of past opportunities is much larger than the number of future opportunities.

Table 1.

LOWER 95 PER CENT CONFIDENCE LIMIT ON THE PROBABILITY OF ZERO FUTURE ACCIDENTS GIVEN ZERO ACCIDENTS IN THE PAST^a

Number of Past Opportunities	Number of Future Opportunities		
	100	1,000	10,000
100	.048	.000	.000
1,000	.740	.050	.000
10,000	.970	.741	.050

^aUsing binomial confidence limits.

The confidence limits, however, do not pin us down to point estimates of the probability of zero accidents with a given number of past and future opportunities. To develop such

³⁸Using binomial confidence limits, based on R.J. Buehler, "Confidence Intervals for the Product of Two Binomial Parameters," Journal of American Statistical Association, Vol. 52 (1957), pp. 482-493, Table 1.

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point estimates, we can use the following idea: in an operation where an accident seems to be possible on technical grounds, our assurance that this operation will not lead to an accident in the future increases with the number of times this operation has been carried out safely, and decreases with the number of times it will be carried out in the future. Statistically speaking, this simple common sense idea is based on the notion that there is an a priori distribution of the probability of an accident in a given opportunity, which is not all concentrated at zero. In Appendix II, Section 2, alternative forms for such an a priori distribution are discussed, and a particular Beta distribution is found to be especially useful for our purposes. With this Beta distribution we can estimate the probability that there will be no accident in the future, given an estimate of the past and future number of accident opportunities. Table 2 gives estimates of this probability for various combinations of past and future "opportunities."

It must be stressed that Table 2 should not be used to find the positive probability of an unauthorized detonation in the future. All it does is to qualify the credence one can have in future safety if one knows only that there has been no accident in the past. Let us assume for example that there have been 1,000 accident opportunities in the past, and that there will be 10,000 opportunities in the future. The probability .091, which Table 2 gives for this case, might then be interpreted as follows: given only the data on past and future opportunities

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and the fact that there have been zero accidents in the past, the estimate of the probability that there will be no accident in the future turns out as low as .091, if we use certain statistical assumptions, which although arbitrary cannot be shown to be unwarranted.

Table 2.

ESTIMATED PROBABILITY OF ZERO FUTURE ACCIDENTS
GIVEN ZERO ACCIDENTS IN THE PAST^a

Number of Past Opportunities	Number of Future Opportunities		
	100	1,000	10,000
100	.502	.092	.010
1,000	.909	.500	.091
10,000	.990	.909	.500

^aGiven a particular Beta distribution, described in Appendix II.

The past record of zero accidents can give much greater confidence if one is concerned about the possibility of several future accidents, rather than just a single one. This might be relevant in the case of unauthorized detonations of small-yield air-defense weapons. One or two such detonations might have no serious aftereffects, but a larger number would create too much public anxiety and could lead to political

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pressures that would suddenly deprive the country of an entire weapon system. Table 3 indicates that greater confidence can be reposed in a system where one or two future accidents are tolerable, again given the fact that no accident has occurred in the past.

Table 3

ESTIMATED PROBABILITY OF NOT MORE THAN TWO FUTURE ACCIDENTS
GIVEN ZERO ACCIDENTS IN THE PAST^a

Number of Past Opportunities	Number of Future Opportunities		
	100	1,000	10,000
100	.879	.251	.030
1,000	.999	.875	.249
10,000	1.000	.999	.975

^aBased on the same Beta distribution as Table 2.

How much, we may ask, would the statistical picture change if one accident did occur? If the accident caused serious civilian damage it would no doubt have drastic effects on political attitudes toward nuclear weapons. This possibility will be discussed later. However, the estimated probability of zero accidents in the future would not increase drastically, except for large numbers of future opportunities.

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The probabilities of Table 4 are relevant to the following situation: assume that an operation has been carried out 1,000 times before the first accident occurs and that the accident could have happened just as well in each of the previous exposures (i.e., that there is no hazard which increases over time, such as metal fatigue). It may be important for national security to continue this operation without interruption, although it will require some time to introduce new safety measures. If the operation has to be continued another 100 times or so, the probability that this can be done without another accident is estimated to be .905.

Table 4
ESTIMATED PROBABILITY OF ZERO FUTURE ACCIDENTS
GIVEN ONE ACCIDENT IN THE PAST^a

Number of Past Opportunities	Number of Future Opportunities			
	10	100	1,000	10,000
100	.905	.368	.00004	0
1,000	.990	.905	.368	.00004
10,000	.9990	.990	.905	.368

^aBased on the Poisson approximation to the binomial distribution, with parameter 1/number of past exposures. See Appendix II for justification of Poisson distribution here.

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In other words, in the absence of additional statistical information, the credence that there will be no accident in the future will be almost as good in the short run as before the single accident happened, so that hasty changes would seem unwarranted.

2. Analysis of Potential Causes of Unauthorized Detonations

Another approach to evaluating the risk of an accident which has never occurred is to analyse how such an accident might be caused, estimate the probability of the possible causes, and then combine these into an estimate of the total risk of an accident. Whether these causes are regarded as a single event sufficient to bring about the accident, or as component contributions to it, will depend on the nature of the causes themselves.

a. Component Events: The Component Probability. An analysis by component events is particularly applicable to malfunction and human errors in the fuzing and firing sequence, because the separate steps of this sequence exist for the very purpose of preventing accidental detonations. Theoretical considerations indicate that a full nuclear detonation will generally require the HE charges to be detonated through the fuzing and firing system. This system, therefore, is crucial for the safety of nuclear weapons, and accordingly most safety studies focus on it (see Bibliography, Section 1).

A great deal of ingenuity has been applied to discover all possible ways in which malfunctions and human errors could

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combine to cause a detonation through the fuzing and firing system. The main risks have probably been identified, but there can be no guarantee that every possible malfunction has been anticipated.

Estimates of the probability of technical malfunction of individual parts of the fuzing and firing system frequently have to be based on informed guesswork. In some cases, however, empirical data are available from quality control statistics. For example, it may have been determined through tests that one out of ten thousand thermal safety fuzes fail to open. Probability figures for human errors generally are a matter of guesswork. Statistics on human errors are hard to collect, partly because errors that do not cause physical damage tend to be under-reported.

Ideally, one would wish to rely on actual observations to estimate the probability of each component event in the chain of events that could lead to a full detonation. Many of these events, however, have never been observed, so that the estimated probability of a future accident would turn out to be zero unless an a priori probability distribution were introduced (see Appendix II, Section 2).

b. Component Events: The Compound Probability. In order to arrive at a compound probability estimate for the final accident, the assumption is usually made that the component events are independent except where technical factors clearly establish

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dependence, such as that between jettison and activation of the contact fuze. In particular, human error probabilities are usually assumed to be independent of malfunction probabilities. This simplifying assumption is dictated by the lack of more detailed data, but it remains questionable in some situations. For example, as already mentioned, one may wonder whether certain human errors are not more likely to occur immediately before jettison than in a normal flight free from malfunction. Some of the incidents with nuclear weapons we cited do indeed show that human errors occur sometimes in rather extraordinary combinations, probably because the first error causes emotional excitement.

An important problem in determining the compound probability of a final accident is the exposure rate. We have to determine the number of "opportunities" when all the necessary component events can occur in the proper sequence. Another statistical problem concerns the tolerance limits and the confidence limits for these compound probabilities. In Appendix II, Section 4, it is shown that the combination of the uncertainties of the probability estimates for each component event leads to huge uncertainties in the compound probability estimate, especially if the number of component events is large.

In concluding, we shall give an example of a compound probability estimation. For this purpose we select a single combination of events (out of the many possible ones) which, on the surface, seems to constitute one of the more serious

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risks. This is the combination of certain malfunctions or human errors with an accidental drop or jettison of certain sealed pit weapons (or AIFI weapons with capsule installed in the guide tube). If regular procedure requires that the safing pins be removed from the weapon during readiness exercises or patrol flights, the compound probability of an accidental nuclear detonation will be the product of the probability of accidental drop or jettison and the probability of malfunction or error leading to closure of the low voltage safing switch (or direct activation of low voltage thermal batteries).³⁹ For purposes of illustration, let us estimate the former probability as 1 : 320 flights with a complete weapon aboard. (According to the experience of the Eighth Air Force in 1957, there was one accidental drop in 320 flights with weapons.⁴⁰) This probability estimate also agrees fairly well with the number of previous jettisons and accidental drops that had occurred in SAC as a whole, but it is likely to be too high in the future in view of newly introduced safeguards in the bomb suspension system.

³⁹Air Force Special Weapons Center, Safety Study of Certain Strategic and Tactical Nuclear Weapons, Addendum, SWC-8S-34, 157, January 1958, (~~SECRET RESTRICTED DATA~~), p. 16.

⁴⁰Eighth Air Force, Office of Operations Analysis, Accidents with Special Weapons, October 1957, (~~SECRET RESTRICTED DATA~~), p. 9.

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For the latter probability there exist no direct observations. AFSWC Safety Studies make an educated guess of 2×10^{-3} .⁴¹ A more empirical estimate would have to be based on analogy. The event we are considering is either a single human error or a single technical malfunction (e.g., a short circuit). A study of forty-five inadvertent firings of FFAR rockets revealed that in most cases a single human error or malfunction was the cause.⁴² Hence the incidence of these accidents may provide a very rough analogy for our second probability. In 18,000 missions flown with FFAR rockets, four inadvertent firings occurred, which gives a probability estimate of $1/4500$. Thus we can write:

Estimated probability of an accidental nuclear detonation during accidental drop or jettison per flight with complete weapon aboard $= \frac{1}{320} \times \frac{1}{4500} = 7 \times 10^{-7}$

The upper 95 per cent confidence limit (according to Buehler's technique; see Appendix II, Section 4) for this probability is 4×10^{-6} . If we assume that there will be 3,000 flights with weapons per year, the expected number of accidents per year owing to these combinations of events becomes 2×10^{-3} ; in a decade it would become 3.1×10^{-2} . Using tolerance limits (Appendix II, Section 4), we can say that we are "99.1 per cent

⁴¹Air Force Special Weapons Center, op. cit.

⁴²Richard L. Krumm and George L. Murphy, Human Factors in Inadvertent Rocket Firings with Special Emphasis on the MB-1 Weapon System, Air Force Special Weapons Center, TR-57-18, August 1957, (~~SECRET RESTRICTED DATA~~).

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sure" that the probability of at least one accident owing to this particular cause within the next ten years is not more than .05 (given 3000 flights with weapons per year).

It must be stressed that this example merely serves to illustrate the method of estimating an accident probability from compound events. Our numbers are estimates or guesses which apply only to the given set of operational assumptions. Changes which have already been introduced in the bomb suspension system should reduce the accidental drop probability considerably, and devices against human errors will reduce the second factor of our compound probability.

c. Single Sufficient Events. We noted earlier that traditional probability estimates based on past observations are only of limited usefulness for our problem. To improve our statistical evaluation we found it necessary to analyze potential causes of the accident, to estimate probabilities for these causes, and then to combine them for the total probability of an accident. Some causes of the ultimate accident break down into several independent component events whose probabilities can be estimated and combined into a compound probability. Other causes, however, produce the final accident directly and are not reducible to independent components, so that a single probability estimate must be found. Intuitively one would say that many of these seemingly direct causes make a serious contribution to the over-all risk of an accident, but usually too little is known to arrive at probability estimates.

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Here are some of the events that could cause directly an unauthorized detonation of a nuclear weapon:

Misinterpretation of a Command: In very taut alert postures it is conceivable that a human error or technical malfunction could cause the firing of an armed nuclear missile. In presently operational weapon systems this risk does not seem real, but for certain future weapon systems it will be important to plan preventive measures against it. We shall say more about this later.

Deliberate Unauthorized Action: This problem has been discussed in the preceding section and is dealt with in greater detail in Appendix I. It is shown there that a statistical evaluation of the risk is extremely uncertain. The difficulties are threefold: (1) the inadequacy of statistics on "analogous" actions (say, arson due to pyromania, homicide due to paranoia); (2) the problem of whether such "analogies" are really pertinent; and (3) the uncertainty as to what constitutes an opportunity for such an action and as to the frequency of these opportunities.

Other Causes: If we estimate the over-all accident probability from the probabilities of potential causes we can never be certain that we have included all possible forms of causation. Hence, even if we were able to estimate a probability for each identified cause, it would give us only a lower limit for the over-all estimate. The upper limit would remain unknown because of the residual class of unknown or unconsidered accident causes. Assume, for example, that we had ignored lightning as a possible

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cause of accidental detonation. If lightning can indeed detonate a nuclear weapon, then we should have added the probability of lightning striking a weapon and detonating it to the accident probabilities arising from other causes.⁴³

Apart from unknown or unforeseen causes, there are some that one can identify but can scarcely evaluate in terms of probability. Sabotage, for example, is a potential cause that does not lend itself to a statistical evaluation.

3. Overall Estimates

We know that an unauthorized detonation of a nuclear weapon is possible. What is the probability that such a detonation will occur within the next five or ten years in one or other of the countries possessing nuclear weapon systems? Or, more significantly, what is the probability that an unauthorized megaton explosion will occur in a populated area?

We can discuss the elements that enter into the over-all probability, but we cannot combine them into a useful estimate. Since we know so little about Soviet weapon programs and operational policies we can say almost nothing about the probability of an unauthorized detonation in the Soviet Union. There are reasons for speculating that this probability is smaller for the Soviet

⁴³An unpublished study made at Sandia Corporation indicates that lightning could not detonate a weapon. Another study concludes that a nuclear detonation resulting from a direct hit by a lightning bolt is not inconceivable. (Armed Forces Special Weapons Project, A Study on Evaluation of Warhead Safing Devices, March 1958, (~~SECRET~~ ~~RESTRICTED DATA~~), 13.

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Union than for the United States: first, the Soviet Union probably has fewer nuclear weapons and is conducting fewer operations with them (no overseas bases, perhaps fewer alert maneuvers); second, she may be able to use only highly skilled, senior personnel in nuclear weapons operations; and third, she may be more worried about insubordination and hence keep weapons in a less ready condition. These arguments, however, depend upon supposititious assumptions. Moreover, there are other factors which might make for a higher accident probability in the Soviet Union. First, a more hurried weapons development may have permitted less quality control and safety testing; second, a greater concern with dud rates (because of inferiority in numbers of weapons) may have led to fewer safeguards;⁴⁴ and third, less cross-checking on safety by independent organizations within the defense program.

One of the most important parameters in an estimate of the accident probability is the future exposure to the risk (i.e. the number of accident "opportunities"). A slight change in operational procedures may increase the opportunities per year for a certain human error by a factor of 10,000; conversely, it may reduce them to zero. A probability that is very small for a single operation, say one in a million, can become significant if this operation will occur 10,000 times in the next five years. It may seem unnecessary to stress again the importance of the

⁴⁴Most additional safeguards increase the dud rate.

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number of accident "opportunities," but one should bear in mind that studies about the safety of nuclear weapons and specifications for military characteristics frequently ignore them.⁴⁵

If the probabilities for each potential cause of an unauthorized detonation could be estimated and if the future number of "opportunities" could be predicted for each of the causes, then the over-all probability would simply be the proper combination of these elements.⁴⁶ Many potential causes might readily be neglected if their probabilities were orders of magnitude lower than those of more important causes. Given the immense complexity of the problem and our meager statistical data, we can at best compute a lower limit for the over-all probability. Even this could easily be misleading for future safety policies.

4. The Proper Cost of Preventive Measures

Weapon safety must generally be bought at a cost in terms of dollars, reliability, and readiness. The dollar costs are

⁴⁵A good treatment of exposure rates can be found in Naval Ordnance Laboratory, Relative Accident Probability Analysis, NAVORD Report 4135, November 1955, (~~CONFIDENTIAL~~).

⁴⁶This combination is a matter of straightforward algebra, but it tends to require very extensive computations. For an example of a combination for the over-all probability for a single weapon system, see U.S. Naval Ordnance Laboratory, Analysis of Alternative Lulu Systems, NAVORD Report 4290, June 1956 (~~SECRET RESTRICTED DATA~~).

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usually the least important.⁴⁷ More serious is the fact that safety measures tend either to increase the dud rates or to place weapons in a less ready and more vulnerable state. The unfortunate relationship between safeguards and dud rates has been shown clearly for fuzing and firing systems.⁴⁸

It does not pay to spend more on prevention, in dollars and in damage to the defense posture, than the expected saving in accident "costs" resulting from this prevention. If we assume a linear utility function,⁴⁹ this idea can be expressed more precisely as follows: the cost of an additional safeguard is justified as long as the expected cost of an accident without the safeguard exceeds the expected cost of an accident with the safeguard plus the cost of the safeguard. While this basic rule may have some value in orienting our thinking, it cannot be used for actual decisions relating to safety devices since most of the figures involved remain unknown.

⁴⁷The non-nuclear components of a nuclear weapon, which include most of the safeguards, cost only about one twentieth of the whole system. See Sandia Corporation Fuzing Symposium, SC-4084 (TR), October 1957 (~~SECRET RESTRICTED DATA~~), p. 10.

⁴⁸R.O. Frantik, The Determination, Application, and Limitations of Circuit Reliability Equations, Sandia Corporation, SC-3288 (TR), April 1954 (UNCLASSIFIED); and A.M. Fine, A Guide to Reliability Analysis for System Design Engineers, Sandia Corporation, TM 45-56-12, March 1956 (~~SECRET RESTRICTED DATA~~).

⁴⁹A discussion of utility functions can be found in John von Neumann and Oskar Morgenstern, Theory of Games and Economic Behavior, Princeton, 1953.

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Sometimes it is feasible to replace operational safeguards (restrictions in handling and storage) by technical safeguards with a gain in reliability and readiness and apparently without loss of safety. New technical safeguards, we should remember, need not necessarily reduce the over-all reliability of a weapon system, since the loss in technical reliability may easily be outweighed by the relaxation of operational restrictions that the new safeguard would permit. In Chapter IV, Sections A and B, we will suggest types of safety device that could bring such a net gain in reliability and readiness.

There have been studies that attempted to find an "acceptable" level of accident risk for nuclear weapons, primarily as a basis for specifications relating to weapon safety (like those contained in the "Military Characteristics"). For example, one approach used the past frequency of individual disasters of different sizes as the "acceptable" expected value (in the statistical sense) of nuclear weapon accidents of corresponding size.⁵⁰ This has some intuitive appeal in relation to disaster sizes that fall within past experience. Society accepts a risk of accidents in both industrial and military operations without demanding that the hazardous

⁵⁰Continental Army Command, Office of Special Weapons Developments, Acceptable Military Risks from Accidental Detonation of Atomic Weapons, June 1955 (~~SECRET RESTRICTED DATA~~); and F. H. Dettmer, Acceptable Premature Probabilities, Armed Forces Special Weapons Project, FC/10570136, October 1957 (~~SECRET RESTRICTED DATA~~).

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operations be discontinued or curtailed. But if these computations of "acceptable" expected values are extrapolated to much larger nuclear disasters they will be harder to justify.

Although such efforts to find "acceptable" levels of risk are of limited value, it is even less constructive to posit that any risk of an accidental nuclear detonation is "unacceptable." Clearly, as long as the physical damage is small and there are no untoward political consequences, the risk of an accidental detonation does not differ from the risk of other military accidents. In fact, according to the above-mentioned "utility" argument, even the risk of a very large nuclear accident cannot be considered "unacceptable" if its reduction would create other and greater risks for the nation as a whole.

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II. POLITICAL AND MILITARY CONSEQUENCES OF
THE RISK IN ITSELF

The mere risk of an unauthorized or accidental nuclear detonation has far reaching political and military consequences. Those who have to decide policies and procedures affecting nuclear weapons are influenced by their attitudes toward this risk. Frequently these attitudes have little to do with actual probabilities, but are swayed by minor weapon incidents, public inquiries and protests, and even by foreign propaganda.

A. CURRENT SOVIET PROPAGANDA

During the past year the Soviet Union has poured out an increasing number of statements and broadcasts about the danger of an accidental detonation of an American nuclear weapon. These statements invariably attribute the risk to the U.S. alert posture, both at home and overseas. The accident theme, coupled with the suggestion that the alert posture and overseas bases should all be abandoned, has been repeated with the striking consistency of a major propaganda campaign.

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Many of the Soviet statements emphasize that an accidental nuclear detonation could lead to global war. Perhaps the first specific remark by Khrushchev about an "accidental war" was made in an interview in May 1957.⁵² He said: "Given the existence of atomic and hydrogen weapons, of missiles and ... rocket technology ..., a war can be unleashed as a result of some kind of fatal error...." In another interview half a year later⁵³ Khrushchev expressed great concern about alleged statements by "American military men" that half of their bombers were always in the air ready for action against the Soviet Union: "How many planes in the air, how many people! Think of the psychotic state involved. If a signal is given -- or if the pilot even thinks a signal has been given -- he will fly toward his objective. The loss of a man's mind can lead to war under such psychotic conditions and bring about a terrible retaliatory blow immediately!" One month later, on December 21, 1957, Khrushchev spoke in Minsk and pursued the same thought in more detail:⁵⁴

⁵²Interview of May 10, 1957, with Turner Catledge of The New York Times.

⁵³Interview of November 22, 1957 with William R. Hearst, Jr.

⁵⁴English text in Foreign Broadcast Information Service, Daily Report, Supplement No. 23, December 23, 1957. (The Daily Reports, USSR & East Europe, provided by the FBIS, will henceforth be cited simply as "FBIS".) This source is classified for "Official Use Only."

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A considerable proportion of the American bombers carrying atomic and hydrogen loads are cruising day and night over various countries where American air bases are located. Imagine that one of the airmen may, even without any evil intent but through nervous mental derangement or an incorrectly understood order, drop his deadly load on the territory of some country. Then according to the logic of war, an immediate counterblow will follow. A worldwide conflagration of war can break out in this manner.

One can, however, also imagine another example: During so-called "protective" flights over the territory on which the air bases are located an accident takes place in the air or the equipment refuses to function, and this is possible no matter how perfect the equipment. In that event, the lethal load will fall on the local population of the country which is allegedly being protected by these aircraft. Millions of people may thus lose their lives.

In a published letter to Bertrand Russell, Khrushchev pointed out that Great Britain was particularly vulnerable to the accident risk: "Just suppose that, by the merest chance -- say, for instance, as the result of an incorrectly understood order -- death-dealing weapons of war are used from American military bases in your country against the peaceloving countries. A crushing retaliatory blow would follow immediately. In such an event, the British people might find themselves suddenly in a situation of atomic war...."⁵⁵

On January 11, 1958, Bulganin, as Chairman of the Council of Ministers, sent a more formal message to the Danish Prime Minister, H. K. Hansen, using the same theme and almost the same

⁵⁵This letter, dated December 7, 1957, and published in the New Statesman of December 21, was in reply to an open letter by Bertrand Russell.

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words to discourage Denmark from accepting U.S. missile bases and patrol operations in her territory. "It is not difficult to understand to what tremendous risks the population of a country is subjected in the skies of which the motors of American planes...are roaring day and night. After all, it can happen that an airman, possibly with no evil intent, but because of a misunderstood order or some nervous mental disorder, will drop an atom or hydrogen bomb on the territory of some country."⁵⁶

Soviet propaganda gives great prominence to the "psychiatric" factor as a cause of accidental detonation. One reason perhaps is that it fits into the general Communist picture of "mad Western warmongers" and "mad American military men." Another reason may be that a Soviet analysis of the whole problem led to the rather shrewd conclusion that the "psychiatric" risk is particularly difficult to disprove. A warning that technical malfunction might cause an accident could have been more easily countered. The "psychiatric" theme was given further prominence by a TASS release and by broadcasts from Moscow conveying a statement by a prominent Soviet psychiatrist.⁵⁷

⁵⁶Text broadcast by TASS (FBIS, January 14, 1958). Similar messages were also sent to other West European governments. For a good compilation of additional Soviet statements on the accidental war see FBIS, "Soviet Propaganda on the Nature of the Nuclear War Threat," RS.18, 25 June 1958, (~~CONFIDENTIAL~~).

⁵⁷See FBIS, January 13, 1958.

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Vasili M. Bانشchikov, director of the Scientific Research Institute of Psychiatry,⁵⁸ argued that a sudden mental disturbance in a member of a bomber crew or among communications personnel on the ground could lead to a nuclear disaster. He then discussed temporary disturbances of consciousness, emphasizing that physiological stress, which frequently occurs in flying, can produce these mental states. The Soviet psychiatrist has chosen to stress the problem of fugues, here considered less important than such disorders as paranoia (see Appendix I). This is in keeping with the organic, physiological orientation of Soviet psychiatry.

The news commentators in Soviet bloc countries persistently exploit incidents with nuclear weapons or aircraft accidents in the West. Sometimes they even fabricate such incidents or completely distort the actual happenings. In July 1957, for example, after an Air Force C-124 was forced to jettison some classified cargo, radio Moscow reported that it had dropped "twenty-five tons of atomic weapons." On January 13, 1958, The New York Times carried a news item mentioning that British concern over plane crashes with nuclear weapons had been alleviated by a report from the U.S. Government about a crash which had occurred without any serious effects. This item was picked up by Radio Moscow and twisted so as to suggest that it

⁵⁸Under the Ministry of Health of the RSFSR. See Central Intelligence Agency, Soviet Capabilities in Clinical Psychiatry, Research Supplement to SI 3-58, February 58, (Official Use Only).

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"was just luck" that the weapon did not explode. "Noted nuclear scientists [in England]," it was said, "had stated that it was only a lucky chance that the temperature generated in such an accident was not high enough to explode the nuclear charge."⁵⁹

On February 14, 1958, the Department of Defense and the Atomic Energy Commission issued a joint statement on the possible hazards involved in the movement of nuclear weapons. This statement explained that an accidental HE detonation, such as could occur in an aircraft crash, "might possibly cause local scattering of nuclear materials in the form of dust;" but that it was unlikely any person exposed to them would inhale dangerous amounts and that there would be teams to decontaminate the area. In a broadcast from Moscow to Germany this statement became an order from the U.S. Defense Department for special units to clear away "atomic dust" caused by crashes of U.S. bombers carrying nuclear weapons. The broadcast referred to the recent crash in West Germany of a U.S. aircraft with an atomic gun aboard and warned that, if a hydrogen bomb had been carried all that would have remained of the town and the whole district would have been "merely atomic dust which the special units... now being formed by the Defense Department" would have had to clear away.⁶⁰

⁵⁹FBIS, January 14, 1958, p. FF 11.

⁶⁰FBIS, February 19, 1958, p. BB 7.

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As one would expect, Soviet propaganda was quick to exploit the accidental bomb drop at Florence, S.C., on March 11, 1958. The Soviet commentators propounded again that it was "by sheer luck" that a nuclear detonation had not taken place and alleged that atomic radiation had contaminated the area. Some Soviet commentaries maintained that there had been nine such accidental drops in the United States since 1954, a figure which seems to be arbitrary (cf. our list of incidents in Chapter I, Section A). A broadcast from Radio Prague brought up the "psychiatric" theme again, exclaiming: "The deranged mind of a pilot seeking fame like Herostratus⁶¹ would be sufficient. It would be sufficient to interpret an order wrongly, to make a small mistake in deciphering a code. Any day, any town in West Europe, in the Middle East, in Italy, or even in the United States could become a Hiroshima of 1958."⁶²

In May 1958 the "psychiatric" theme was again played up by Radio Moscow in several broadcasts referring to a fictitious "secret report" by Dr. Frank Berry, Assistant Secretary of Defense (Health and Medical), which allegedly stated that 67 per cent of the Air Force officers and enlisted men were

⁶¹Herostratus is known for having burnt the temple of Diana at Ephesus, one of the Seven Wonders of the World, in 356 B.C. He confessed that he did so merely to eternize his name.

⁶²FBIS, March 17, 1958, p. HH 4.

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psychoneurotics.⁶³ The broadcast on this to England wound up with the standard conclusion: "These flights of U.S. H-bombers, manned by crews driven to frenzy, are a tremendous menace to humanity. They must be stopped."⁶⁴

Again, on June 18 -- to cite only one more of the many examples -- Pravda exploited an unauthorized take-off and crash landing in a B-45 by a mechanic at the American Huntington base in England. In an article criticising statements by General Power about the airborne alert, Pravda maintained that it could be judged from this incident "what precision the U.S. Air Force has in reality....Can the propagandists of a 'push-button war' guarantee that a drunk or mentally deranged pilot is not going to press the terrible button of war?"⁶⁵

The most obvious interpretation of the Soviet propaganda campaign on nuclear weapon accidents is that it is aimed against the U.S. alert posture and foreign bases. Its primary target seems to be public opinion among U.S. allies, but to some extent it may also be directed toward Americans themselves. By keeping anxieties about nuclear accidents alive, the Soviet Union can increase the political opposition to nuclear weapons and American overseas bases. It is of course unlikely that an

⁶³The "secret report" had its origin in the photostat of a faked letter from Dr. Berry to the Secretary of Defense, published by the East German newspaper Neues Deutschland.

⁶⁴FBIS, May 9, 1958, p. BB 32.

⁶⁵FBIS, June 19, 1958, pp. BB 14-17.

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allied government would deny base rights or over-flights to the United States as a direct result of the Soviet accident propaganda. Its effects may be more subtle: through the medium of public discussions and parliamentary debates the allied governments may become so accident-conscious as to show additional caution and reluctance in future negotiations with the United States.

This interpretation is supported by the fact that the Western Allies of the United States were the main targets of the Soviet accident propaganda, although some of the statements were also addressed to the Soviet public. Furthermore, the timing of the peak propaganda effort suggests a tie-in with the campaign for prohibiting nuclear weapons and with the dispute about the sharing of U.S. nuclear weapons with NATO allies.

Beyond its obvious attempt to degrade the Western nuclear alert posture, the Soviet accident propaganda may be intended to benefit the Soviet Union in the event that a serious unauthorized detonation does in fact occur in a U.S. or British weapon system. Propaganda before the event might be expected to aid Soviet exploitation of the disaster after it happened. The Soviet Union could then certainly claim: "We told you so!"

Another possible interpretation of the Soviet statements is that there may be some genuine concern among Soviet leaders about the risk of an accidental war as a result of an unauthorized nuclear detonation. Some support for this hypothesis can be

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found in the occasional Soviet discussions of the accident risk that are not directly designed for foreign audiences.⁶⁶ It is doubtful, however, if Khrushchev genuinely felt the fear he expressed when he warned: "The world is in a situation in which, by virtue of just one absurd incident or damage to the operational gear of a single plane carrying a hydrogen bomb, or as a result of the slightest deviation from the normal in the mentality of the pilot behind the controls, war can become a fact this very day."⁶⁷ If we are to take such statements as an expression of genuine concern, we must first show how an

⁶⁶For example, the Soviet Air Force newspaper, Sovetskaya Aviatsia, published an article on April 9, 1958, which started with the incident at Florence S.C., and went on to discuss the fuzing mechanism of atomic bombs in considerable detail. The propaganda content of this article must be addressed to Soviet-bloc air force officers rather than to the Western public, since the foreign distribution of this newspaper is limited. Beyond this, the article conveys a fairly objective picture of the risk of an accidental detonation, which seems to apply to Soviet atomic weapons as well as to American ones. For example: "A forced landing of the carrier aircraft, an accident in the air, various faults in the bomb-mounting system, errors or criminal actions on the part of the crew or of technical personnel who prepare the carrier aircraft for flight -- these are just a few of the factors which might lead to the dropping of an atomic bomb. The experience of many years of work by specialists with various types of explosive devices has also shown that even comparatively successful designs may in a number of cases function incorrectly. For example, there are known instances in which aerial bombs have exploded prematurely in flight. Completely satisfactory detonator designs also produce a certain number of failures under combat conditions." Translated in The Current Digest of the Soviet Press, Vol. 10, No. 16, p. 28.

⁶⁷In a letter to Bertrand Russell, published in The New Statesman, March 13, 1958, as a reply to a letter from John Foster Dulles.

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unauthorized detonation could in fact lead to an "accidental" war, or at least, how the Soviet leaders might believe that it could. In Chapter III we shall argue that, at the present time, a single unauthorized nuclear detonation could scarcely by itself cause an all-out "accidental" war. But this problem requires additional study.

B. CURRENT ALLIED REACTIONS

Among the allies of the United States, the United Kingdom has displayed the most explicit public reaction to the risk of an unauthorized or accidental nuclear detonation. Various debates in Parliament provide a rather clear picture of the thinking on this subject in the British government and political parties. The first debate, on November 27, 1957, was sparked by a question from Aneurin Bevan as to whether American aircraft on patrol duty from British bases were armed with hydrogen bombs. (This question may have been suggested by a statement that General Power, Commander of SAC, made on November 12 concerning the alert status of SAC.) In answer to subsequent questions Prime Minister Macmillan said that the bombs could not be activated without "considerable technical adjustments." An editorial in The Times commented: "If the crew can fuse the bombs on a routine flight, one can only hope and trust there is no possibility that a code-word, ordering immediate offensive action, could be misheard or misread."⁶⁸

⁶⁸ November 29, 1957.

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The debate on this issue was resumed early in December in a more detailed discussion of the hazards from an aircraft accident. Prime Minister Macmillan assured the House of Commons that, if a plane carrying a nuclear weapon crashed, there would be only a limited hazard, arising from the possible oxidation of plutonium.⁶⁹ A few days later Barbara Castle, a left-wing Laborite, asked whether United States aircraft carrying hydrogen bombs on patrol in the United Kingdom were also carrying the "apparatus" for arming them. Upon receiving an affirmative answer from the Prime Minister she said in a rather well informed manner: "Is it not now clear that these bombs can be armed in flight in a matter of minutes by remote control from the crew cabin?"⁷⁰ While this is a correct picture of the Automatic Inflight Insertion Mechanism, there remains the question whether the planes about which the Laborites were so exercised actually had the nuclear capsule aboard.

The alleged hazards of a crash by a bomb-carrying plane were used repeatedly by the opposition party as an argument that patrol flights from the British Isles should be stopped. For example, Zilliacus, another left-wing Laborite Member of Parliament, asked whether the Prime Minister would forbid the carrying of nuclear weapons by airplanes, since it was now known that a crash "could result in infecting an area of 100

⁶⁹The New York Times, December 4, 1957.

⁷⁰The Times (London), December 13, 1958.

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square miles or more with deadly plutonium."⁷¹ While other members of the opposition did not express themselves so strongly, the Labor Party headquarters and the Trades Union Congress declared that flights with nuclear weapons should be stopped because of the accident risk.⁷² This gives a foretaste of the restrictions under which the American bases in the United Kingdom might have to operate if the Labor Party should come to power in the next elections. While the moderate "Gaitskell line" probably would not impose a great change upon present operations, any future increase in flights with weapons in pursuit of an airborne-alert policy may well be opposed.

The impact of actual mishaps with nuclear weapons is illustrated in a renewal of the "accident" debate in the House of Commons following the accidental drop at Florence, S.C. Members of the opposition again demanded that flights with nuclear weapons be stopped.⁷³ It goes without saying that such an incident, or a more serious one, in Great Britain itself,

⁷¹Weekly Hansard (Commons), No. 410, p. 206 (28 January 1958).

⁷²"We consider that the Government have failed to show that it is necessary for British-based aircraft to carry nuclear weapons on either patrol or training flights. Any military advantage that there may be in such patrols is far outweighed by the risk that a war might be started by accident....There is also the danger of radio-activity resulting from a crash.... In short, flights with nuclear weapons by British-based aircraft should be limited forthwith to those necessary for the transport of weapon stocks." The Times, March 7, 1958.

⁷³Weekly Hansard (Commons), No. 417, pp. 1105-1114 (March 18, 1958).

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for instance one involving plutonium contamination, would lend new vigor to the opposition campaign.

In the political life of other countries the risk of nuclear weapon accidents has so far played a less conspicuous role than in the United Kingdom. In West Germany the debate centered upon the question whether the German army should have nuclear weapons at all. Those opposing nuclear weapons used mainly moral and political arguments (e.g., reunification would become more difficult), or stressed that in the event of war West Germany would be worse off because her possession of nuclear weapons would draw the enemy's attack and make the country a nuclear battleground. The peacetime risk of accidents, however, was not stressed so much, in spite of East German propaganda which spread the Moscow line on this subject.

Public attention in Western Europe was drawn to the nuclear accident risk mainly by the debate in the British parliament. Communist propaganda, too, played a part in this. It is interesting that the anxieties among our allies -- or, more precisely, among their left-wing parties -- are focused on airborne weapons. Possible hazards from stored Matador warheads, Honest Johns, and atomic artillery have caught less attention. There seems to be a notion that nuclear missiles on the ground are safer than nuclear bombs in the air.

C. PROBABLE FUTURE CONSEQUENCES OF THE RISK

Political attitudes toward the risk of an accidental detonation will doubtless have an increasingly serious effect on

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Western military policies and on the over-all defense posture. Sooner or later the trends in operational policies, combined with weapon developments, are likely to draw increasing governmental and public attention to the risk of an unauthorized or accidental nuclear detonation. Future minor mishaps with nuclear weapons, which are not entirely avoidable, will further stimulate this attention. As a result, restrictions will probably be imposed on new operational concepts or on the use and deployment of new weapon systems. This may be done by the Department of Defense and the Air Force on their own initiative in anticipation of political difficulties, or as the result of a request from Congress or, in case of overseas bases, from foreign governments. In some cases these restrictions may cause a serious degradation of the defense posture and even vitiate the utility of a new weapon system altogether. Let us remember that after the accidental drop and HE explosion of a [REDACTED] bomb at Florence S.C. -- a relatively harmless incident -- all flights with weapons of B-47's and B-52's were suspended until new safety measures could be introduced. There are certain possible contingencies that ought to be considered in forming future plans affecting nuclear weapons. Some of them are discussed below.

SAC Airborne Alert

One of the measures to insure survival of a retaliatory capability is to keep part of SAC constantly airborne with

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weapons aboard. A large airborne alert is presently under study as a future operational procedure for SAC. This operation may be seriously affected by political attitudes toward the risk of a nuclear accident. An airborne alert policy will generate certain mishaps with nuclear weapons, which will increase public concern about the risk of an accidental full detonation. This concern will in turn create political pressures against the airborne alert policy and may jeopardize its continuation.

Incidents that will stir up fears of a full detonation are:

- (1) Aircraft crashes which lead to conspicuous effects from the weapon, such as a noticeable HE detonation, contamination detected by the public, or a fractional nuclear yield.
- (2) Accidental drops and jettisons noticed by the public, especially those that cause contamination or civilian damage from the HE.⁷⁴

The number of incidents in the second category for a given airborne alert policy is difficult to predict. Past experience indicates there are roughly three accidental drops or jettisons per thousand flights with weapons. Recent technical adjustments

⁷⁴After the incident at Florence, S.C., SAC formed a new policy for the emergency release (jettison) of war reserve weapons. This release is to be restricted to ocean areas (or designated water masses within the ZI). Hence only uncontrolled drops may attract public attention in the future. Cf. Air Force Special Weapons Center, Safety Study of Nuclear Weapon Suspension and Release Systems of USAF Aircraft, SWVN 58-11, June 1958, (~~SECRET RESTRICTED DATA~~), p. 4-5.

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and revised procedures, however, should substantially reduce the probability of an accidental drop. Furthermore, only part of the drops that occur will result in detonation (high or low order) of the HE. Among the four jettisons and two or three accidental drops in the past that have come to our attention, an HE detonation occurred in only two of the drops. The weapon must have a fair impact velocity, perhaps over 300 ft/sec, and must hit hard ground. Past jettisons over the ocean seem to have been without HE detonation.

Since our second class of mishaps seems to give little cause for alarm, we shall concentrate on the first category, the aircraft crashes. A certain number of aircraft crashes is unavoidable. If we can show that in a large airborne alert these alone will probably generate political pressures, we shall have made our point, and the additional number of accidental drops, which is harder to predict, will serve to reinforce the argument.

The number of aircraft accidents to be expected in an airborne alert can be estimated from the forecasts of the Directorate of Flight Safety Research, according to which there will be 5 major aircraft accidents per 100,000 flying hours for the B-52. Let us assume that the "learning curve" will reduce this rate to 4 per 100,000 flying hours. Not all of these aircraft accidents, it may be hoped, will result in conspicuous damage from the weapons aboard, such as an HE explosion or contamination. The meager data on hand show that of five

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aircraft crashes with weapons aboard in the past all resulted in an HE detonation, but let us assume that only two-thirds of the aircraft accidents will lead to conspicuous effects from a weapon. A large airborne alert, with one-tenth of SAC's B-52's constantly airborne would amass about 440,000 flying hours per year, so that the expected annual number of "conspicuous" weapon accidents becomes $440,000 \times \frac{4}{440,000} \times \frac{2}{3} \sim 12$. This, it should be noted, is a conservative estimate. If we include an expected number of accidental drops at the rate of 1 per 1000 flights, which is only one-third of the rather high rate in the past, and assume that only one-third of these drops will result in a conspicuous incident, we have to add another seven incidents to the twelve allowed for aircraft crashes.

Let us now look at the political complications that might arise from an Air Force policy that led to a dozen or more incidents a year involving an HE detonation and/or contamination from a nuclear weapon. Since eighty per cent of all aircraft crashes occur within three miles of a base, most of these incidents would be in inhabited areas. Thus, if there was some plutonium contamination, the public would usually learn about it. Hopefully, the Air Force would be able to decontaminate or fence off the immediate hazard area and convince the public that no further danger existed. However, the area in which the presence of some plutonium could be detected with a good alpha meter might be as large as ten square miles. If the public's attention were drawn to this residual contamination an unfortunate

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political argument might well develop. Some self-styled "experts" on radiation hazards who opposed current U.S. defense policies could use such methods to evaluate the plutonium hazard as to make vast areas seem unsafe for permanent habitation. The layman would be unable to form an objective opinion since the computation of safe plutonium contamination levels is exceedingly complicated and involves little known parameters. The unfriendly "experts" could exploit the fact that the original laboratory tolerance dose, long since published by the Atomic Energy Commission, is one thousand times lower than the current unpublished dose, which is accepted by the services and the Atomic Energy Commission.⁷⁵ The latter dose is based on careful studies and leads to the conclusion that the area of dangerous contamination would be small and manageable.

Once a contamination incident provoked public arguments, it would probably lead to political pressures for a curtailment or interruption of the airborne alert, especially abroad. Let us recall that all flights with weapons were temporarily

⁷⁵The original dose of one microgram of plutonium per square meter was an arbitrary one, simply representing the minimum amount that was detectable with meters available at the time. It is mentioned in The Effects of Atomic Weapons, 1950, p. 257, footnote. According to the new evaluations, permanent habitation is safe in areas where the plutonium concentration, after decontamination, does not exceed 1000 micrograms of plutonium per square meter. See, for example, Strategic Air Command, Headquarters, Disaster Control Team Conference [July ?], 1958 (UNCLASSIFIED), p. D,8; and Air Force Special Weapons Center, Effects of Plutonium Contamination on Air Force Operations, TN-56-64, March 1957 (~~SECRET RESTRICTED DATA~~).

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discontinued after the harmless incident at Florence, S.C., and that severe restrictions were imposed -- and to some extent still are imposed -- on the operational use of the MB-1, even without any outside political pressures.

It would be possible to avoid plutonium contamination altogether by using weapons that do not contain plutonium (such as the Mark 15 Mod 2, Mark 39 Mod 1, and Mark 36 — X 2). This would probably reduce or at least postpone political difficulties. Even these weapons, however, would still leave a small area of uranium (in the form of or alloy) contamination,⁷⁶ as well as the effects of the HE detonation.

What has been said here about the political implications of mishaps with nuclear weapons arising from a SAC airborne alert applies also to incidents that might result from aircraft crashes in connection with a rapid take-off of the ground alert forces. The probability of aircraft crashes may be higher during such emergency take-offs than during normal operations.

IRBM and ICBM Communications and Dispersed Stockpiling

According to current plans the Thor missiles that will be transferred to the United Kingdom will have a fifteen-minute alert posture. An equally short alert time will probably become the goal for other IRBM's and for the ICBM's. Such a posture requires an almost immediate response through the entire

⁷⁶An area about fifty times smaller than that to be expected from plutonium.

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command chain down to the launching pad or launch control trailer. An extremely short alert time, of course, raises the problem of accidental firings.

We can expect that most of the governments in the countries where missiles are to be based will want to guard jealously their control over the launching of an IRBM from their soil. The first few IRBM bases may fail to stir up politically motivated inquiries, and the authorities may initially be satisfied that the risks inherent in short alert postures can and must be borne. As the number of missiles increases, however, concern about the command structure is likely to grow, perhaps stimulated through parliamentary debate. At this point, a discrepancy between de jure control and de facto control may be brought into the open. A more careful investigation may reveal to the host countries that the rules which require their consent for missile launching are not backed-up with technical provisions to make them effective. Apart from the allied countries, should American authorities themselves consider that the controls set up by agreement are not sufficiently supported by technical and operational arrangements, the Air Force might find its task more difficult.

Even if the current IRBM systems remain unaffected by such political concern, future systems with dispersed bases and quick reaction times could become the target of serious objections. For example, the Minuteman system will have solid fuels that permit faster launching than liquid ones and dispersed

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bases that increase the problems of control. Unless advance preparations have been made to meet political concern about the safety of the command system,⁷⁷ the Air Force may find restrictions imposed on it from outside which will seriously degrade the readiness of one or more of its missile systems.

It is sometimes argued that the vulnerability of our retaliatory capability would be reduced if the stockpiles of nuclear weapons were more widely dispersed. According to one concept, for example, the vulnerability of SAC might be reduced by dispersing part of the bomber force to suitable municipal airfields, where bombs would have to be stored. An important objection to this idea is the risk of an accidental detonation. Thus, if this scheme should turn out to be desirable on other grounds, it may still be unacceptable to the Government because of a conservative attitude towards this risk.

The risk of an accidental detonation also has a pervasive effect on the present restrictions concerning nuclear weapons. This effect is not always fully understood by military people, who take it for granted that nuclear weapons have to be closely controlled and that they must work within limits set by legislators and administrators. If we analyse these restrictions, it appears that they arise from fear of an unauthorized full detonation. It follows, then, that if this fear could be

⁷⁷In Chapter IV, below, we shall suggest what such preparations might be.

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reduced by safety measures some of the restrictions could be avoided.

To summarize, the effect of the risk of an unauthorized nuclear detonation -- or, more precisely, of governmental attitudes towards this risk -- is measured by restrictions imposed on nuclear weapons that go beyond security from espionage and beyond the restrictions ordinarily imposed on HE ordnance. If confidence in weapon safety is improved, the United States may avoid some serious degradations of its present defense posture, and even more in the future.⁷⁸ This is one of two reasons why we suggest that an effort be made towards new safety measures.⁷⁹ The other reason will be discussed in the next chapter, namely the possibly catastrophic consequences of an actual unauthorized detonation.

⁷⁸We suggested above certain degradations that may occur in the future; a more detailed account of present degradations would lead beyond the security classification of this report.

⁷⁹See below, Chap. IV.

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III. POSSIBLE POLITICAL AND MILITARY CONSEQUENCES OF
AN ACTUAL UNAUTHORIZED DETONATION

A. THE IMPACT ON ALLIANCES AND THE CENTRAL DEFENSE POSTURE

It is obviously not feasible to make specific predictions about an event which is so unprecedented and which may take place in a wide variety of circumstances. Some people predict that an accidental war would immediately follow a large unauthorized nuclear detonation, while others think that our defense posture and political position would remain basically the same.

Let us try to imagine the political consequences of an unauthorized nuclear detonation ranging in yield from 10 to 100 kilotons and causing catastrophic civilian damage at the place of explosion. The United States could absorb such a disaster without disruption of her economy or political structure. In a country like England or West Germany, the scars of such an accident would be less severe than those of World War II and could be healed much faster. Nevertheless, it might have unfortunate political consequences.

In the parliaments of allied countries the parties opposed to nuclear weapons or American bases (the Labor party in Britain and the Social Democrats in West Germany) might well be swept into power if there were an election shortly after a nuclear disaster. Alternatively, the government parties in power might have to reverse their stand on nuclear armaments. These effects

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might extend beyond the country where the disaster occurred. The reaction in allied countries whose governments are less subject to pressure from public opinion, for example Turkey and Formosa, is harder to predict. The worldwide result of such a disaster could well be the effective demobilization of many American overseas bases, although many of the political basing agreements might survive.

An unauthorized nuclear detonation in the megaton range would probably lead to more severe effects, especially if it produced fallout. It could lead to the virtual or actual nuclear disarmament of one or more NATO countries, or even drive them into neutrality. The fallout itself could cause considerable economic disruption in the country where the disaster occurred, and -- civil defense preparations being what they are -- there would be casualties far outside the area of destruction. The inevitable cases of delayed radiation sickness, the task of reconstruction in the blast area, and the psychological effect of such a large death toll would dominate the political climate for some years.

The political effects would go far beyond the proper fields of military concern, such as nuclear armament, military alliances, and base rights. If skillfully exploited by the Soviet Union they could lead not only to an increase in neutralism but even to a peaceful expansion of the Soviet sphere of influence. During the initial period of shock in the Western World the Soviet Union might be expected to seize the initiative by

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offering incentives to "anti-nuclear", pro-Soviet alignments.

Finally there are the political and military consequences within the United States itself. One effect is definitely predictable. There would suddenly be acute anxieties about peacetime operations with nuclear weapons, not only among the public, but in Congress and even among the services. The resulting restrictions would surely go far beyond all our present ones. It seems almost certain that the country's ability to respond to surprise attack would be severely reduced, either through a curtailment of service control over strategic nuclear weapons or through the prohibition of various peacetime operations.

B. THE SABOTAGE PROBLEM

One cannot fail to be impressed by the overwhelming political and military advantages the Soviet Union would gain from an accidental nuclear detonation within a U.S. or allied weapon system. Is it safe to assume that the Soviet Union will always take a passive attitude toward this possibility?

There are two principal ways in which this kind of sabotage could be accomplished: through an agent using an American weapon; or by means of a Soviet weapon exploded at an American or allied nuclear-weapon base. The former method would have the great advantage that the United States itself might not be able to determine whether the detonation was due to an act of sabotage, a human error, or a technical accident, especially if

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the saboteur was killed in the act. Disadvantages of the method would be the difficulty and uncertainty of recruiting a saboteur who could get access to a weapon⁸⁰ and the risk of discovery before the plot was accomplished.

If the Soviet Union used one of its own weapons it could easily control the timing, arrange the plot on short notice, or call it off at the last moment. Overseas, the weapon could perhaps be smuggled by truck into a storage area. Here the most important risk would be that an investigation might show that sabotage was involved. The fallout composition and yield of a smuggled weapon would, in all likelihood, indicate that the detonation could not have been due to a U.S. weapon. Furthermore, the bomb crater might well be too far from the area where U.S. weapons had been located.

⁸⁰Soviet propaganda media gave considerable publicity to anonymous letters which the Soviet Embassy in London said it had received early in July, 1958, from somebody who pretended to be a U.S. Air Force pilot in Britain. This letter-writer threatened to drop an atomic bomb off the English coast and then seek asylum in the Soviet Union. By drawing attention to this incident, the Soviet Union was able to contribute further to the anxieties about nuclear weapons in England, an issue discussed in the previous Chapter. However, intentionally or unintentionally publication of these letters also has a secondary effect. Such pranks as these letters, which might have been written by a paranoid person, stimulate other mentally deranged people to similar acts. A case in point is the discharged R.A.F. man, obviously a paranoid, who wrongly pretended to have been the author of the first letter after it became public. The Soviet Embassy must have become the recipient of quite a number of "crank letters" after this incident. In fact, on September 18, 1958 they made another one public.

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Evidently the overall risks of such a sabotage plot would be considerable for the Soviet Union. Detection might not only deny her most of the anticipated gains; but it could also lead to a serious loss since the United States would have to institute severe countermeasures. As long as the evidence of sabotage remained equivocal the Soviet Union might deny it with enough success to ensure that the detonation increased neutralism and adversely affected American overseas bases. By far the most serious risk for the Soviet Union would be that of starting an all-out attack by the United States. This risk has two aspects: first is the possibility, to be discussed below, that any large detonation, whether arising from accident or sabotage, may trigger a war; second, is the chance, which the Soviet leaders would have to consider beforehand, that the United States might embark on an all-out attack as a punitive action if it should discover that sabotage was involved. We would guess that the latter risk would be the least important deterrent against the scheme.

C. THE RISK OF AN ACCIDENTAL WAR

We cannot possibly cover the vast subject of accidental war in the present study. Yet we are bound to say at least a few words about it. The following remarks should be taken as no more than preliminary and tentative thoughts on the role an unauthorized nuclear detonation might play in causing an accidental war. Let us define "accidental war" as a central

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war between the major nuclear powers that breaks out when neither of them intend it.

Theoretically there are perhaps three principal ways in which the unauthorized detonation could lead to an accidental war: (1) The country in whose military sphere the detonation happens may mistake it as the first bomb of a surprise attack and execute immediate retaliatory action. (2) The other side, learning of the detonation, may fear that just this will happen and therefore execute a preemptive attack. (3) Such a detonation would put the forces on both sides into an alert which, if it got out of hand, could take on the appearance of hostile action and so induce a large-scale attack.

(1) Accident Mistaken as a Surprise Attack.

It seems unlikely that an unauthorized detonation would be mistaken for the beginning of a surprise attack by those empowered to order retaliatory action. With all the discussion and concern about nuclear accidents it is hard to believe that the top decision makers and their advisors, upon receiving the news of a single nuclear explosion, would not consider the possibility of an unauthorized detonation. One would expect them to look into the circumstances of the detonation before ordering an irrevocable all-out attack.

Khrushchev has claimed that "a crushing retaliatory blow would follow immediately" if a nuclear weapon were launched accidentally from an American base in the United Kingdom against

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a Communist country.⁸¹ However, the Soviet leadership must know that a well-planned surprise attack would have an immensely better chance of success than a hasty "retaliatory blow," especially at a time when the American forces were already alerted. The accidental delivery of an American (or British) nuclear missile on a target in the Soviet bloc would undoubtedly force the Soviet leadership to make drastic demands, which the West would probably have to reject. This in turn might lead to some "retaliatory" action, but unless the time were favorable for an all-out nuclear attack on the American forces that action would probably be on a limited scale.

(2) Preemptive Attack for Fear Accident Will be Mistaken for Surprise Attack.

If an accidental nuclear detonation occurred in a Western country, there would in theory be a risk that the Soviet leaders might immediately order a "pre-emptive" attack on the United States to forestall any American action that might spring from a mistaken belief the detonation was part of a Soviet surprise attack. A Pravda editorial, commenting on Krushchev's proposal to Eisenhower of July 2, 1958, that new steps be taken to prevent a surprise attack, expressed the fear that some such chain of events might take place. "There is no guarantee," said Pravda, "that an accidental explosion of an American nuclear

⁸¹In a letter to Bertrand Russell, published in the New Statesman, December 21, 1957.

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bomb on the territory of the United States or another country of the West would not be regarded as a surprise attack. Such an accidental explosion might cause a new world war."⁸² It seems doubtful, however, that the Soviet leaders really believe the United States would react so precipitately to a single accidental detonation.

(3) Post-Accident Alert on Either Side Mistaken for Indicator of Impending Attack.

It is to be expected that alert measures would be initiated by both sides immediately after a large nuclear accident. The country in whose sphere the accident happened might be expected to alert some of its forces in case the detonation should prove to be of enemy origin. If the alert consisted in making a large part of the bomber force airborne, the other side might respond with a similar maneuver. The question is whether either of these movements might be mistaken for the beginning of an attack and thus precipitate a preemptive strike. An evaluation of this risk would require a separate study of

⁸²FBIS, Daily Report USSR & East Europe, July 7, 1958, p. BB 4. Some weeks earlier Khrushchev himself had spoken to the same effect: "What is to gainsay the possibility that an accidental explosion of an American atomic or hydrogen bomb on American territory, or on the territory of some other nation over which American H-bombers are flying, may be taken for a surprise attack? There is nothing to guarantee that this will not happen. Thus, an accidental atomic bomb explosion may well trigger another world war." (Speech at Warsaw Treaty powers' meeting in Moscow, May 24, 1958.)

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intelligence and alerting procedures. One would suppose, however, that the cause of the mutual alert, a single detonation, would soon be recognized on both sides as an accident. In this case the mutual alert would seem less menacing than one whose cause was unclear to one or the other side. The latter might occur as a result of mistaken tactical intelligence about an impending attack.

In spite of its menacing sound, the risk of an accidental war does not appear to be the most serious potential consequence of an unauthorized nuclear detonation, although this may no longer hold true when missile forces, with their short alert, become predominant. At present, in our judgment, the most serious consequence of an unauthorized detonation in the Western defense sphere would be a substantial deterioration of the Western military and political posture. This view takes no account of the disaster itself, which might cause great damage and casualties.

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IV. CONCLUSIONS AND SUGGESTIONS

A. FUTURE OBJECTIVES FOR WEAPONS SAFETY

The Nuclear Weapon System Safety Group at the Air Force Special Weapons Center is concerned with the safety of systems currently in use or in development and has recommended many improvements. By and large, these recommendations focus on the non-nuclear parts of nuclear weapon systems and generally suggest modifications of concepts already developed by the AEC or by Air Force contractors. The original specifications for a warhead are worked out earlier between the DOD and the AEC, and formalized in the Military Characteristics which provide the broad guidelines for the AEC development programs. It is toward these earlier stages in warhead development, rather than toward the work being done within the Air Force by the group at AFSWC, that this first suggestion of the present study is directed.

The basic idea is simple. The requirement for weapon safety should not have to be satisfied at the expense of important operational uses. Instead, optimal operational use of weapon systems should provide the guidelines for future work on warhead safety. Most of the technical devices that increase safety also increase the chances for duds; hence a compromise is always necessary between safety and reliability. This compromise, however, should not be made only in the light

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of wartime needs; it should also take account of the peacetime defense posture. In Chapter II we showed that lack of confidence in technical safety features can lead to serious restrictions in the peacetime operation and maintenance of nuclear weapons. These restrictions may be serious for two reasons: they usually increase vulnerability to enemy attack (for example, because of centralized storage or few airborne weapons) and decrease the readiness for defensive and retaliatory action (because of disassembled or unloaded weapons).

It is our feeling that frequently the over-all effectiveness of a weapon system could be increased by additional technical safeguards whose small contribution to the dud probability would be more than compensated by the fact that these safeguards would render some restrictive operational or maintenance policies unnecessary. Putting it somewhat bluntly, and perhaps a little unfairly, the military requirements for reliability in nuclear weapons are sometimes so stringent as to prevent the weapon designer from adding certain safeguards. This tends to result in a weapon that leaves policymakers worried about safety. The weapon, therefore, has to be kept disassembled or "buried."

Thus the weapon system may be much less reliable in an emergency than one with more elaborate safeguards. Well designed safeguards reduce weapon reliability very little, if at all.

Given this idea as a starting point, one may inquire whether new approaches to weapon safety are possible. An additional incentive for new approaches lies in the trends of

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future weapon systems, which will make problems of weapon safety increasingly more acute; for example, shorter alert times for missiles, perhaps an increased airborne alert for SAC, and possibly very high yield anti-missile weapons. In all these developments the U.S. defense posture could be substantially strengthened by nuclear weapon safeguards that would give a nearly absolute guarantee against unauthorized detonations.

It is often said that the only absolute guarantee would be to abolish nuclear weapons altogether. The impracticality of this statement should not blind us to the possibility of novel approaches to the technical aspects of warhead safing that could have a large pay-off. A small research and development effort, perhaps on a more basic level than the traditional fuzing and firing systems, could bring the services substantial advantages in the operational use of future nuclear weapons. Moreover, such an effort might prevent a large-scale disaster some day.

This is not the place to make specific suggestions for such a research and development program. All we wish to point out here is that the Air Force, like the other services, has a genuine interest in such a program and that its military objectives ought to be worked out so as to facilitate the related AEC activities. As for the contents of such a program, it might be desirable to explore the feasibility of a sealed pit weapon where part of the HE or the X-unit is easily removable, thus regaining the safety of weapons with removable capsules

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without incurring their disadvantages.⁸³ It might be thought worthwhile to develop devices that give complete assurance against a fractional nuclear yield in case of accidental fire, particularly in high-energy missile fuels.⁸⁴ Conceivably devices could be developed for certain weapon systems that would permit full arming only over enemy territory.⁸⁵

These examples are only arbitrary illustrations, and we wish to emphasize that we do not feel competent to describe a specific research program or to propose new weapon safing principles. We merely suggest that the military objectives in the field of weapon safety be expanded, so as to encourage novel approaches to the particularly tough problems set by future operational concepts. Service action along these lines

⁸³We are indebted to Dr. John S. Foster, Livermore Radiation Laboratory, University of California, for this suggestion as well as for more general ideas on such a program. A research program along these lines has now been started at Livermore. Errors or mistakes in this discussion are, of course, ours.

⁸⁴Part of the HE could perhaps be made to detonate at a lower temperature than the rest, so as to always guarantee a low-order or, at least, an asymmetrical detonation.

⁸⁵This suggestion may not be as outlandish as it seems at first. The ATRAN arming signal for the TM 61-B (Matador) in essence provides such a feature.

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will help the appropriate AEC groups to orient their research towards these objectives.⁸⁶

B. MEASURES AGAINST HUMAN ERRORS AND DELIBERATE UNAUTHORIZED ACTIONS

Technical and operational measures that prevent unauthorized action will also prevent inadvertent human errors, while the reverse is rarely true.⁸⁷ We have seen that there is a risk both of human errors and of deliberate unauthorized acts leading to a nuclear detonation. Since the second risk seems the greater, we shall concentrate on the measures that prevent deliberate unauthorized acts. These measures will be, a fortiori, effective against human errors. Where measures are not applicable to both kinds of risk we shall consider those which apply to inadvertent human errors alone.

1. Nuclear Weapons Handling

According to studies done at the Armed Forces Special Weapons Project and the Air Force Special Weapons Center, most

⁸⁶Sandia Corporation has indicated on occasion in the past that new safing principles could be developed if the services so desired. See their suggestion that "an easily removable plug (or other link) in the critical warhead circuitry" could be designed to obtain better safety for sealed pit warheads than that obtained with the presently contemplated battery removability. (Armed Forces Special Weapons Project, FC/1257-423, A Study on Advantages and Disadvantages of High Voltage Power Supply Removability Provisions in Atomic Weapons, December 1957, ~~SECRET RESTRICTED DATA~~), p. 28.

⁸⁷Non-technical measures to prevent unauthorized acts, such as personnel selection and personnel security measures, are less effective in preventing human errors.

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sealed pit weapons could be detonated full-scale by a single person who succeeded in gaining access to the warhead and who possessed "a knowledge of the warhead electrical circuits, a handful of equipment, a little time, and the intent."⁸⁸ Such a person might even use timing devices to permit his own escape; although self-preservation need not be important to persons with certain mental disorders (see Appendix I). While the traditional type of sabotage may well be prevented by existing security provisions, the present personnel selection and screening procedures cannot eliminate the risk that someone with official access to nuclear weapons will commit an unauthorized act as a result of an abnormal mental state.

Here is a serious weakness in weapon safety that needs to be remedied. The Air Force Special Weapons Center has already recommended that the AEC, in designing future weapons, consider the ease with which sealed pit warheads can be intentionally detonated full-scale "and make sabotage as difficult and/or time-consuming as possible."⁸⁹ The sealed acceleration switch developed by Sandia Corporation for certain later missile warheads will make an unauthorized detonation before launching so difficult as to be practically impossible.⁹⁰

⁸⁸ Air Force Special Weapons Center, Preliminary Study of the XW-49/Thor, SWVN-58-2, January 1958 (~~SECRET RESTRICTED DATA~~), p. 2.

⁸⁹ Ibid., p. 3.

⁹⁰ This switch is being considered for use in the TX-41 and TX-45.

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To meet the hazard from sealed pit warheads that do not have such a switch, the present policy is to apply stringent security measures and restrictions to the handling of the weapons. As was pointed out above, such restrictions have certain disadvantages. First, they tend to degrade the overall defense posture by reducing readiness or dispersal; second, most of them could be circumvented by careful planning over a period of time, and a capacity for patient plotting is sometimes found in conjunction with certain mental disorders; and third, such restrictions may take the form of governmental prohibitions on the adoption of new operational policies that are militarily desirable. These prohibitions will be less likely to the extent it can be demonstrated that an unauthorized nuclear detonation is impossible.

Two kinds of safety device might conceivably help to reduce the need for awkward handling restrictions. First, it is perhaps worth asking whether the above-mentioned acceleration switch or an equivalent safeguard could be retrofitted into existing sealed pit missile warheads. The technical problems and cost of doing this could probably be determined fairly easily, and the Air Force could then weigh the advisability of applying such a safeguard to all missile warheads where feasible.

A second suggestion applies particularly, though not exclusively, to bombs, where the acceleration switch may not be feasible or may not serve the purpose. A small study program might be instituted to examine the technical feasibility and

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operational implications of some form of "lock" sealed inside the warhead as a safing device. The idea behind such a device is simply to eliminate the possibility that a detonation can be caused by tampering directly with the weapon itself. A combination-lock may be preferable to a simple lock and key, since it would facilitate control of activation by a central command. Combinations could be transmitted in a moment to any point in the field or to airborne planes, together with an order to attack or to carry out a war-plan mission.

The idea of a "lock" may not find ready acceptance. At least two arguments may be brought against it:

(1) It introduces a risk that the weapon cannot be detonated when it should be. The transmission of a combination may break down in an emergency or after enemy attack. The dud rate due to technical component failure will not increase, however, if the "lock" takes the place of another safety element of equal reliability.

(2) The concept of "locked" weapons may be thought psychologically harmful. At first sight it appears to run counter to military tradition and to imply that certain weapons cannot be fully entrusted to the crews or ground personnel. The psychological objection can best be met by recalling that the existing removable nuclear capsule, whose place the "lock and combination" might take, has established a precedent for removing from air crews the power to cause a full detonation on their own responsibility. Indeed the practice of withholding

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from personnel in the field full control over certain very sensitive operations in not alien to military tradition. It is commonplace in cryptography and some form of the practice has often been seen in highly secret wartime activities.

The risk that weapons might be inoperative when they have to be used presents no insurmountable problem. A "lock" would certainly not be put into every weapon. One would expect it to be undesirable in a large number of weapon systems. Moreover, it seems possible that a "locked" weapon could be armed more readily in an emergency than a weapon requiring the insertion of nuclear capsule. According to one study, it takes ten to fifteen minutes to load a capsule on a plane,⁹¹ while the transmission and use of a lock combination could be accomplished within seconds. Finally, a weapon with a "lock" may permit new peacetime operations and strategies that would otherwise remain unacceptable to the appropriate government authorities. For example, political authorization of an airborne alert with sealed pit weapons for certain overseas bases might hinge on such a feature. The "lock" might also facilitate meeting the American requirements for ultimate control of nuclear warheads in weapon systems of allied countries.

An idea as simple as this is obviously not new, and it has found mention in many earlier studies about weapon safety. In fact, an initial development program has recently been started

⁹¹Headquarters, Strategic Air Command, Offut AFB, Project Tryout, July 1957 (~~SECRET RESTRICTED DATA~~).

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by the USAF Nuclear Weapon System Safety Group (at AFSWC) upon a request by Hq. SAC. We have argued this case so extensively because wider acceptance is required if this development is to become effective. Furthermore, if this "lock" is to be sealed inside selected warheads, the AEC may need concurrence by the other two services. For weapons aboard a plane the locking device could perhaps be located in the equipment associated with the aircraft, but for safety during the entire stockpile-to-target sequence the locking device would have to be in the weapon itself.

2. Missile Command Structures with Short Alert Times

We must now turn to the question whether an accidental or unauthorized launching of a missile is possible. The acceleration switch for certain missile warheads, mentioned above, removes the hazard of unauthorized detonation during ground handling, but cannot prevent a full detonation in the event of accidental or unauthorized launching. Furthermore, owing to the short alert time the launch operations have to be fast and simple, and the cost of round-the-clock manning makes it desirable that only a small number of people be needed to launch a missile. According to present plans, the initial operational Thors will require just two actions to start and complete the fueling and launching, and these could be performed by a single person in the launch control trailer. Normally, however, two to four people will be present in this trailer. It can hardly be denied that there is a risk of unauthorized acts. The current

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technical arrangements should make it practically impossible that a missile will be launched as a result of a series of inadvertent errors, but the possibility of a disastrous deliberate unauthorized act cannot be precluded by this means. Those near the launch controls who opposed such an act might be overpowered or deceived, particularly if there were only two people present in all.

Communication links in the command chain may also be susceptible to the risk of unauthorized acts that might lead to the launching of a missile. There may be various relay points in the communications systems for missiles where a single person of lower rank could, in a short alert posture, initiate a missile launching. It is still too early in the development of these systems to pinpoint all the places where such an act is possible.

Here we have analyzed the command and control system only for the initial operational Thor as programmed for bases in the United Kingdom. We shall use this example to show how a missile control and communications system could be designed so as to eliminate the risk of unauthorized launchings, without increasing the reaction time or the vulnerability of the command chain to enemy action. As far as we can determine this important objective has not been pursued consistently in the designing of missile communications.

Our example gives, of course, only the general principles of a missile control system. The final design for such a system would have to take account of the actual war plans that govern

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the launching of missiles under a variety of emergency situations.⁹² Furthermore, the technical apparatus adopted for each system must first go through development engineering, which should take full advantage of the most modern communication techniques to meet the rigorous demands for security and reliability.

The shaded parts and heavy lines of Figure 1 represent the proposed safeguards against unauthorized firings, which would be added to the existing communications structure of the Thor.⁹³ The missile itself is safeguarded against unauthorized acts by a lock that can be opened through an electrical code. This lock has to interrupt some essential element of the launching process, for example the fuel inflow (in liquid propellant missiles). The lock itself could be protected against unauthorized tampering and sabotage through a burglar alarm system.

⁹²Command systems are affected by basic political considerations, such as the provisions governing authorization by the President for the use of nuclear weapons (and by allied governments in case of overseas bases). Also the war plans for alternative military headquarters and alternative command chains must be taken into account in the final communications system.

⁹³Jack B. Carne's contribution in developing the technical aspects of this example is gratefully acknowledged. Some of the VHF and HF radio links here proposed are not included in present designs and would have to be added together with our proposed safeguards.

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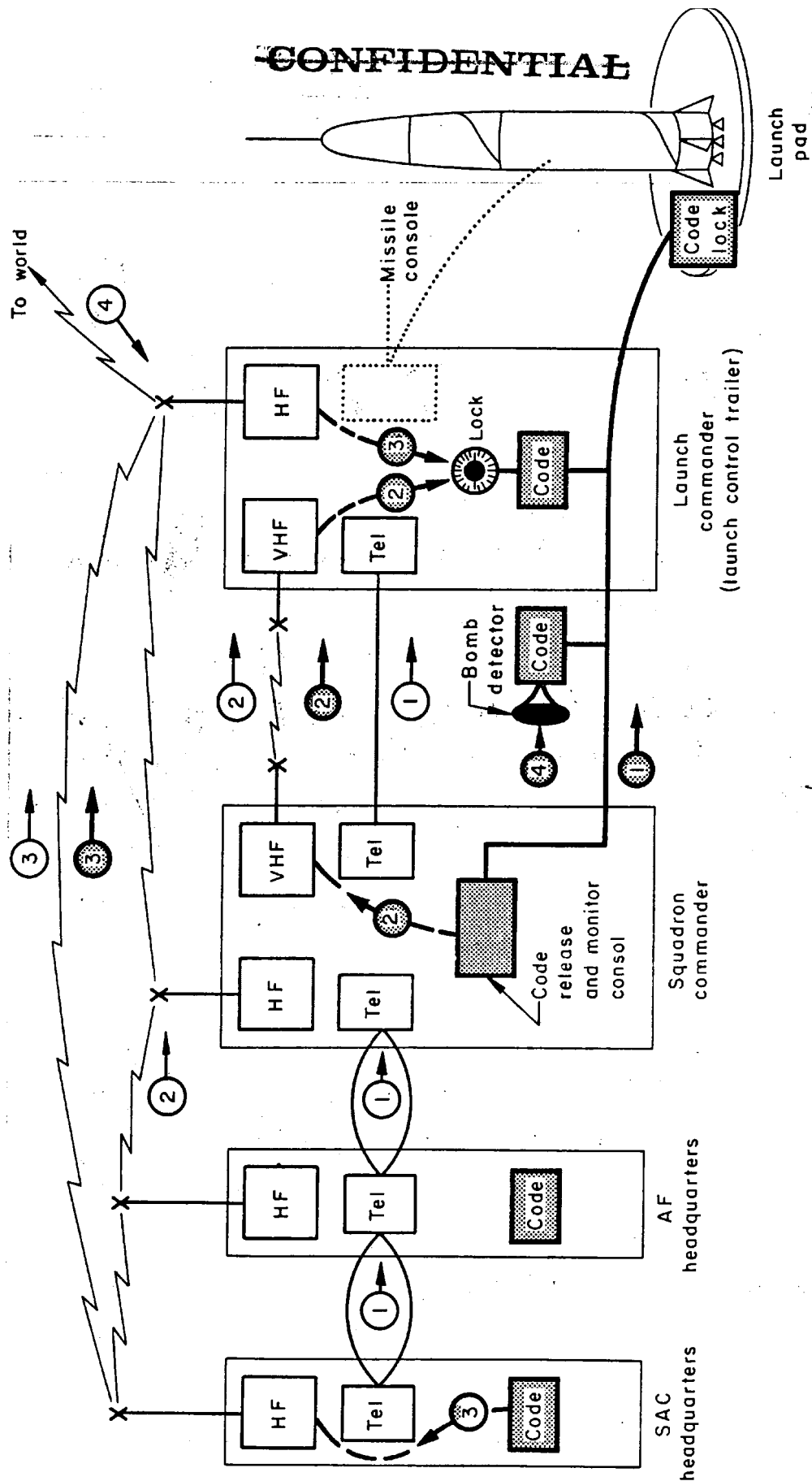


Fig.1—Example of missile control system safeguarded against unauthorized launching

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In our example we have four alternative modes for releasing the missile and transmitting the command to launch it. In the first (preferred) mode the launching order would come over one of the alternative telephone circuits from SAC Headquarters, through divisional headquarters (e.g. 7th Air Force), to the Squadron Commander. The Squadron Commander would then transmit the order to his five Launch Control Trailers by telephone circuit and instantly activate the code release circuit, which would open the lock at the missile itself. This would enable the Launch Commander to complete the count-down.

Incidentally, the code release circuit might also be used to monitor the alert condition and count-down of the missile and to relay this information to the Squadron Commander. If desired, this circuit could be continued into SAC Headquarters and perhaps be used for selecting one of the two alternative targets programmed in the missile.

The second mode of release could be used if one of the telephone links and/or the code release circuit are interrupted. In this case the order would be transmitted over radio links (HF between SAC Hq. and Squadron Commander, and VHF between Squadron Commander and Launch Commander). Then the Squadron Commander would take a numbered code out of his code release console and transmit it via the same VHF link to the Launch Commander, who in turn would apply the code number to a separate

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combination lock⁹⁴ that would activate the code release circuit and open the missile lock.

The third mode could be used if the Squadron Command were destroyed but the Launch Control Trailer and missile still were operative. In this case SAC or Air Force Headquarters could transmit the launch order directly over the HF radio link to the Launch Commander and use the same link to transmit the code number for releasing the missile. The Launch Commander would then proceed as in the second mode.

Finally, a fourth mode has been devised for use in the event that the HF link with SAC Hq. is also interrupted, or in the event that SAC, 7th Air Force, and Squadron Headquarters are all destroyed, but some missiles with their Launch Control Trailers still survive. Destruction of Squadron Headquarters by a nuclear weapon will be registered by a bomb detector (close to the Launch Control Trailer) which will automatically activate the code release circuit and open the lock at the missile. (Such a bomb detector would also release the missile lock in the third case, and transmission of the code over the radio links would then be only for back-up.) At this point the Launch Commander would be on his own and could use his HF receiver to listen to other radio stations so as to establish whether or not he should proceed according to a war plan prepared for this

⁹⁴Preferably a faster device than the combination locks of a safe; perhaps a device like a telephone dial.

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contingency. If it is thought undesirable that the Launch Commander have the power to launch missiles without direct orders from SAC Hq. or the Squadron Commander, the fourth mode may be left out.

The strongest argument in favor of a control system like the one outlined above is that it will reduce opportunities for unauthorized acts. Moreover, it should be emphasized, it does not increase vulnerability. In all conceivable situations where a missile survives undamaged, the ability to launch it is preserved.

The system might also shorten reaction time between the issuance of a launching order from the top and the execution of the order at the Launch Control Trailers. For this there is a psychological reason. In a command structure which does not have such special safety features there would unavoidably be a lingering fear among many of the people involved that a malfunction or an error might "start World War III." This might well have a retarding, even a paralyzing, effect on human performance at the very time when the fastest action was required. It is easy to visualize the psychological hesitations of an officer in the field when he is supposed instantly to implement an irrevocable action of whose enormous implications he is fully aware. As long as there is doubt in his mind as to whether a mistake or misinterpretation is involved, he will be predisposed to disbelieve a launching signal and to go beyond the normal verification process. This could lead to disastrous delays.

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In the past, signals for irrevocable military action were usually preceded by strategic warning that conditioned field officers psychologically to go into action. Just the reverse holds true today. The events which signal that deterrence has in effect failed and that World War III has started are likely to be such an abrupt and shattering departure from everyday experience, even for many military men, that they will evoke the psychological defense mechanism of incredulity.⁹⁵ Where these events do not immediately impinge upon weapons personnel, the factors of disbelief and fear of accidents are likely to be so much the more inhibiting.

⁹⁵At Pearl Harbor, even with all the strategic warning available, military men doubted a large number of tactical warning signals. Particularly pertinent to the psychological reaction that we have in mind here is the following example: a Navy air patrol on the Sunday morning of the attack sank an enemy submarine one mile off the Pearl Harbor entrance. When the report of this incident was telephoned to the Operations Officer for Admiral Bellinger, he asked if the message had been properly authenticated, because in the back of his mind there was the feeling that it might quite possibly have been a mistake, a drill message of some variety that had gotten out by accident. (Although drill messages were regularly required to begin with the word "drill.") While he was waiting for authentication, he saw the first enemy plane make a dive on Ford Island and started to make out a report of violation of flight rules, assuming that it was a young pilot "flathatting." (From a forthcoming RAND Report, Signals and Decisions at Pearl Harbor, by Roberta M. Wohlstetter.)

A similarly pertinent incident was reported after a false air-raid alert on the west coast on May 5, 1955. One of the switchboard operators, who was supposed to start the sirens when a certain warning light flashed, instead called the repairman, assuming there was something wrong with the light that made it flash.

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A communications system which eliminates the risk of human error or deliberate unauthorized acts that could cause the launching of a missile is indispensable, not only for reasons of safety, but also because it will add greatly to the reliability and speed of the response to an actual launch command. It seems likely that missile systems other than Thor, for example Minuteman, would benefit equally from such a command and control system as we have described.

3. Selection and Supervision of Critical Personnel

Efforts further to improve personnel selection and screening procedures seem less promising for the prevention of deliberate unauthorized acts than technical and operational safeguards. Since some of the pertinent mental disorders (or predispositions to abnormal temporary mental states) are exceedingly hard to detect, screening procedures aimed at complete prevention would have to be time-consuming and expensive, and even then their reliability would be questionable. More important, it would seem psychologically objectionable and harmful for morale to introduce elaborate psychiatric screening procedures for all personnel connected with special weapons. For these reasons our emphasis is on technical safeguards. Were the technical safeguards here suggested in full operation, however, there would still be a few places in most weapon systems where complete reliance would have to be placed on lower rank personnel, who must perform rather monotonous duties like

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round-the-clock manning of control points in a communications system. In allocating personnel to a limited number of crucial duties it would be feasible to use "positive selection" procedures, that is, to select people particularly suited for these jobs, rather than to screen out unsuited people. While "positive selection" and screening are two aspects of the same thing, the former avoids the objectionable implications of the latter. Furthermore, there is an important difference in the testing procedures: in order to select only a few people out of a large number, it is feasible to reject many for apparently slight reasons without harm to morale or manpower; but in the unselective screening of a large number of people excessive rejection rates are undesirable.⁹⁶ The freedom to select, without concern about those left out is necessary, since the discriminating indices are so uncertain.

We plan to come back to this idea of "positive selection" in a later report. We may add that this concept is quite common in the services; such fields as intelligence and cryptography have traditionally used special selection procedures.

⁹⁶ It has been shown that it is easier to ensure satisfactory performance ("positive selection") than to screen out psychiatrically unsatisfactory personnel. Thus, in a sample of psychiatrists' predictions of satisfactory military performance, 90 per cent of the estimates were accurate, as against only 25 per cent of those for unsatisfactory service. In other words, in the latter group 75 per cent would have been eliminated on the basis of the predictions although they actually performed satisfactorily. Albert J. Glass and Francis J. Ryan, "Psychiatric Prediction and Military Effectiveness," U.S. Armed Forces Medical Journal, Vol. 7 (1956), p. 1585.

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The supervision of those charged with the critical responsibility of screening out individuals with dangerous mental disorders would be primarily the responsibility of medical officers. To assist medical officers in the detection of potentially dangerous mental disorders, they ought to be given guidance about the more detailed psychiatric aspects of unauthorized destructive acts (see Appendix I). The early symptoms of these very infrequent types of medical disability may not be fully familiar to all the medical officers. Furthermore, if they are officially informed about this problem, they can also more easily advise commanding officers. At the same time, this kind of information, we would definitely recommend, should be restricted to the medical officers. Havoc would result if laymen attempted to make diagnoses in this area.

C. PUBLIC INFORMATION POLICY

1. For Minor Accidents Involving Nuclear Weapons

Future peacetime operations in the Air Force, as well as in the other two services, will make it almost inevitable that nuclear weapons occasionally become involved in aircraft crashes, transportation accidents, or similar mishaps. This may bring out latent fears about an accidental nuclear detonation and about an "accidental" war as the possible consequence of such a detonation. Abroad these mishaps may also stir up political antagonism against U.S. military operations. If these fears and political attitudes affect governmental decisions,

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they may result in unfortunate degradations of the U.S. defense posture. This effect has been discussed above. We have also seen how Soviet propaganda has consistently exploited past mishaps in order to aggravate the political and military embarrassment of the United States. Hence the great importance of a well-planned public information policy on nuclear weapon mishaps.

Public information officers have given considerable attention to this problem, and several steps have already been taken to prepare the public for minor mishaps and to allay anxieties. There have been two public releases, issued jointly by the DOD and AEC, about the consequences and possible hazards of accidents involving nuclear weapons: the News Release No. 124-58 of February 14, 1958, and the Technical Information Bulletin of September 30, 1958.⁹⁷ The former has been fairly widely and favorably reported in the domestic press. Soviet propaganda broadcasts, however, utilized it to scare Western European nations about nuclear accidents, a side-effect of such news releases that is probably unavoidable.⁹⁸

The public information program must be kept up to date to adapt it to foreign propaganda developments and political reactions among hostile, neutral, and allied countries, and to

⁹⁷AEC-DOD, Technical Information Bulletin on Atomic Weapon Accident Hazards, Precautions and Procedures, September 30, 1958 (6 pp.).

⁹⁸See page 63 above.

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take account of the changing peacetime operations with nuclear weapons in the three services. It seems desirable to maintain close coordination in this field among the three services, DOD, AEC, USIA, certain overseas commands, and -- with the necessary modifications -- the U.S. allies and allied commands.

We wish to prevent any impression that we are advocating more publicity about nuclear weapon accidents. Although a successful public information policy does require the release of some information, there is a risk in the field of weapon safety that the educational program may be carried too far. Our analysis of weapon incidents in Chapter I reveals a trend in public information policy towards more and more candid releases. Five years ago, for example, when an accident on a base resulted in [REDACTED] killing more than a dozen people, it was successfully explained to the public so that no discussion of atomic weapons arose. Contrast with this the Florence, S.C., incident in 1958, which -- although it only killed a few chickens -- was followed by detailed public discussions about the malfunctioning of the bomb release (e.g., the astonishingly accurate Time article of March 24). While the policy that was successfully used in the past may no longer serve in the future, it would still seem desirable to avoid frequent public references to the presence of nuclear weapons in aircraft crashes. In jettison incidents, such phrases as "classified cargo" have been used with success.

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Different information programs are necessary for the different types of minor accident involving nuclear weapons. Reference to the presence of a nuclear weapon in an aircraft crash may frequently be avoided, all the more easily if access to the immediate scene of the accident has been restricted for reasons of public safety and security. Since most aircraft crashes create a hazard from the fuel, these restrictions will not always require a reference to nuclear weapons.

We hope to say more about public information policies for minor weapon accidents at a later time. Here we wish to make only one more specific suggestion, which relates to the public acceptance of incidents involving local plutonium contamination. In an accident where the HE of a plutonium-containing weapon detonates, plutonium dust may be scattered over a considerable area. The size of the dangerously contaminated area would be small if evaluated in terms of the tolerance dose (permissible concentration on the ground) which is based on currently accepted but unpublished studies of the AEC and DOD. However, the old tolerance dose long since published by the AEC is one thousand times less. As we have shown above, this could lead to an unfortunate public argument with untoward political consequences for the services.⁹⁹

Two steps could be taken to reduce the risk of exaggerated public views about the plutonium hazard in the event of a

⁹⁹Page 75-77.

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contamination incident. First, the studies in support of the higher tolerance levels could be published in scientific journals. This should be done without attracting unnecessary attention to weapon accidents, perhaps by relating the plutonium dose to experimental situations or reactor accidents rather than to weapons. Second, the Atomic Energy Commission may find it possible to announce publicly its acceptance of the new tolerance dose, since the original dose was nothing but a very conservative estimate, based simply on the lowest concentration that instruments of that time could detect. These steps should not take the form of a public information campaign. On the contrary, they should be taken in a routine fashion without attracting publicity. Once this information is a matter of open scientific record it can be used to allay public debates after a contamination incident.

2. After a Large Unauthorized Detonation

It would be presumptuous to suggest a public information policy for the event of an unauthorized nuclear detonation, but some advance thinking and planning seem desirable. Should such a disaster occur, the official reaction to it would strongly influence the political and military consequences. Since the official position would have to crystallize very fast in order to mitigate the consequences, there would be little time for reflection and no time for research after the event.

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The official reaction toward such a catastrophe would obviously be decided at the highest government level, but the branch of the service concerned with the event, and perhaps the AEC, would have to be brought in to provide an interpretation, especially as to the possible causes. It is at this point that consideration of the sabotage problem (see above Chapter III, B) would have to enter. If the possibility of sabotage cannot be ruled out, public information policy must somehow reflect this, for the United States will surely not desire to accept blame for a disaster that the enemy might have knowingly brought about.

To mitigate some of the political consequences of a nuclear disaster it might be useful to anticipate the political reaction to the disaster and deprive it of some of its force. In addition to such a "counter-offensive" in the field of public information, the disaster area should, and obviously would, be given all possible aid.¹⁰⁰

¹⁰⁰ More research must be undertaken before this important subject can be fully elucidated.

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APPENDIX I

PSYCHIATRIC ASPECTS

By Gerald J. Aronson, M.D.

Unauthorized destructive action (UDA) by military personnel may result from four causes. Our problem is to identify and describe these causes, to assess their importance, and to suggest means of screening and prevention which may reduce the probability of the cause operating in such a manner as to produce UDA.

A. THE FOUR CAUSES OF UNAUTHORIZED DESTRUCTIVE ACTION

The factors producing UDA may be grouped into four classes:

1. Sabotage -- actions authorized by a foreign power or, clearly and rationally, in the interests of a foreign power and against the interest of the United States.
2. Accident -- mechanical and/or human error where human motivation to cause UDA is at a minimum of deliberateness, clarity, and rationality.
3. Misperception or Misunderstanding of an Order -- closely allied to accident, this category differs in that a man might commit UDA deliberately, clearly, and with the rationale of having been authorized -- an honest mistake, as it were.
4. Derangement -- mental disorder, acute or chronic, in which the act may be deliberate and clear in its motivation but irrational in terms of common human understanding.

Considerable overlap exists between accident, misperception and some forms of derangement. In addition, from the ranks of the mentally deranged step forth some of those destined to be

traitors, spies, and saboteurs.¹ Little can be said about the psychiatric aspects of treason, accidents, or misperception except within the framework of the mental derangements and their precipitants.

B. A CATALOGUE OF DERANGEMENT

A man, with opportunity and access, with ability and desire, commits UDA. What manner of man is he? From what does he suffer and what are his motives? What events precipitate and translate his motives from prisoners inside his skull into UDA? How can he be detected before he has opportunity and access -- or, detection failing, how can he be prevented, after he has opportunity and access, from joining his intent to his ability to bring about UDA?

The more blatant forms of mental illness, acute or chronic, need not be considered here since these would have prevented induction or continued training of the overtly ill person. Hence the fully-developed symptoms, the hallmarks, of the pertinent disorders will not require emphasis. Instead the minimal cues, the "soft" signs, of the various illnesses will be briefly described.

Three groups of mental disorder can lead to UDA in civil and military life:

¹E. G. William Joyce, John Amery, Kenneth Edward and Stoker Rose. See Rebecca West, The Meaning of Treason, Viking Press, New York, 1947.

1. Paranoid schizophrenia and or paranoia
2. Disorders of impulse control or psychopathy
3. A miscellany of temporary states: psychomotor epilepsy, "fugues," pathological intoxication, etc.

1. The Paranoid Group of Disorders

The Standard Nomenclature² differentiates this group into paranoid schizophrenia (Nomenclature No. 000-x24), paranoid state (000-x32), paranoia (000-x31), and paranoid personality (000-x44); but these disorders merge imperceptibly into one another and may all be considered together. Of the above-listed major three groups of mental disorder, this paranoid group is the most dangerous and produces the highest yield of senseless destructive acts in civil life.

Of the seven attempts, successful and unsuccessful, on the lives of Presidents of the United States, six were committed by paranoid personalities (for example, John Wilkes Booth, the assassin of Lincoln) or paranoid schizophrenics. None of these six people were criminal. Although family and close friends often commented years before the attempted assassination on the peculiarities and eccentricities of the assassin-to-be, none was so blatantly ill as to have been hospitalized; strangers had not observed their lurking madness.

²Standard Nomenclature of Diseases and Operations, fourth ed., published by the American Medical Association, Blakistone, Philadelphia, 1952.

In fact, even after the attempted assassination, medical experts had testified as to the sanity of the assassin in the majority of these cases. It is of further interest to note that during the interval from the hatching of the idea to assassinate the President to the actual attempt (a period from two weeks to several years) these madmen were able to act in a manner conventional enough to avoid attention and detection. During this interval they planned carefully, and sometimes wisely, to add opportunity to intent -- and did so without arousing suspicion. Of relevance is the fact that each paranoid assassin was a man alone -- without collaborators. The attempt on the life of President Truman in 1950 by Collazo and Torreasola was a joint effort; in this instance there is no evidence clearly suggestive of derangement in either of these Puerto Rican Nationalists.³

a. The Latent or Sub-Clinical Paranoid Condition. That the paranoid reactions may lurk undiscovered for many years and escape detection at induction, during schooling, training, or supervised work may receive confirmation not only from clinical experience but from also the statistic that, in the Army, one third of all separations for psychosis were initiated after two years of service.

Hence it may be important for physicians and senior commanders to become familiar with the minimal cues, the "soft"

³Robert Donovan, The Assassins, Harper and Brothers, New York, 1952.

signs, of the paranoid disorders and their precursors. These signs are seen normally in every individual from time to time and only their preponderance, association together, and duration become suggestive of a latent, or sub-clinical paranoid condition.

The soft signs of the paranoid group of reactions:

Arrogance -- the assumption of superior or unique abilities.

Humorlessness -- a relative inability to laugh at oneself, one's mistakes, and one's foibles.

Jealousy, suspicion, envy.

Stubbornness -- a relative inflexibility in entertaining new notions, particularly if these notions originate with other people.

Preoccupation with one or two dominant ideas, filling one's waking life, taking precedence over interpersonal relationships, and narrowing the range of interests.

Sensitivity in interpersonal relationships -- unusual preoccupation with status; feelings of being left out, ignored, ridiculed, or talked about.

Vengefulness and a relative inability to let bygones be bygones in unimportant matters.

Overalertness to real or fancied personal slights and injuries and to departures from highly rigid codes or regulations.

"Memory like an elephant" -- especially for facts bearing upon one's own competence and capability; memory reaches far back into the past to document and buttress one's position.

A certain persuasiveness and intensity in argument -- supported by what appears at times to be almost too logical or watertight argumentation.

This group of people may serve well in civil and military life, at times because of the traits above and, at other times, in spite of these characteristics. Because of the intensity of their poorly controlled hostility, they may seek jobs or positions where these hostilities may be discharged in a socially acceptable manner. Five extracts of case material from among Air Force personnel (both students and qualified flying personnel) illustrate this motive in choice of flying:⁴

1. "I fly with a tiger attitude. Flying is a thrill, a great kick...I get a wild blue yonder feeling."

2. "The Air Force is my way of life. I never want to leave or have another way of life. I love combat. I dropped bombs at anything--kill them all, as many as you can, hospitals included...I prefer low altitude to high altitude bombing and strafing because it's personal. You see them when you shoot them and the bullets hit..."

3. The third case extract is that of a 34-year-old Major who was assigned to SAC as third pilot in the B-36. "In bombers you get bored, going on and on for hours. I get a helluva feeling of being let down if I'm not working and doing something all the time. I enjoy flying by myself. I don't like the responsibilities of others or having others responsible for me. I enjoyed the war. I enjoyed dropping the bombs, shooting at the trucks. It's a helluva thrill. You don't know what it is unless you've done it."

4. A 23-year-old pilot, a Lieutenant, had difficulty in maintaining social contacts, fearful of disapproval and anxious to please. A few hours after he had to say "Sir" to someone, he was overwhelmed with fantasies of tearing that person apart. He enjoyed the violence

⁴ From Charles Sarnoff, Medical Aspects of Flying Motivation -- A Fear-of-Flying Case Book, Randolph AFB, Texas, October 1957.

of judo class. He felt like exploding when in crowded restaurants; this feeling lessened when hostile fantasies of "tearing the place apart" occurred. He suffered anxiety attacks every two weeks or so in connection with hostile or sexual thoughts. To him flying was exciting, rewarding in its expression of hostility and power.

5. A fifth case illustrates a full blown paranoid schizophrenia in a 33-year-old pilot (a Captain) without impairment of flying proficiency in a B-25. He had felt his new job as Food Service Officer to be overwhelming and became confused, grandiose, inappropriate, and demanding. He felt that his men regarded him, rather than the commanding officer, as their leader and he wrote letters giving orders to his commanding officer. During this period of schizophrenic confusion he logged eight hours on the B-25 with unimpaired proficiency.

None of the first three men were clinically ill and none had difficulty in flying. The fourth was listed as obsessive-compulsive neurosis, and the fifth case as suffering a psychotic episode. Further, although none of these men is clearly paranoid, the intense, poorly controlled hostility in the context of effective job performance, is a feature making future paranoid development appear more probable than for the average person.

b. The Transition from a Latent to an Overt Paranoid Condition. Fortunately there is no smooth and inevitable trajectory from a paranoid condition that is latent or sub-clinical to an overt paranoid state in which a senselessly violent act may occur. Few persons suffering a latent paranoid condition become clinically paranoid and fewer still commit a violent act. Nonetheless the fact that paranoid tendencies may insidiously and malignantly develop into a full

fledged paranoid condition with its attendant hate, fear, and vengefulness makes it necessary to know some of the symptoms of this insidious development and to be alert to the precipitating events of this psychic alchemy.

The symptoms of the transitional period are many and varied but, almost always progress from a feeling of being slighted or unappreciated, through feelings of being ignored, to notions of being watched, pursued, slandered, attacked, subverted, etc., by which time the clinical illness is clearly in evidence.⁵ Objectively, the transition from latent phase to the clinical appearance of the condition is often marked by muscular tension and rigidity, hypochondriasis with frequent bodily complaints, and sleeplessness. This triad of symptoms almost certainly accompanies the interval of time during which the violent act is being contemplated (weeks to months). Impairment in work efficiency is a common though by no means a certain sign preceding the commission of a violent act.

c. Precipitants for the Paranoid State and UDA. The precipitants are not easily specified since the eruption of a full-blown schizophrenic psychosis, no matter how sudden or insidious, may seem to come out of the blue and without apparent cause to one who does not know the individual or his

⁵
Cf., Karl Menninger, The Human Mind, Knopf, New York, 1948.

history. Nonetheless it is possible to touch upon some precipitating events or situations not uncommonly serving as the hammer blows on an already predisposed personality:

(1) Sleeplessness. Prolonged wakefulness of 36 to 72 hours or more may be a critical factor in the precipitation of some psychotic illnesses.⁶

(2) Social Isolation, Prolonged Boredom, and Sensory Deprivation. Increasingly of late, evidence has been brought forth to show that depriving an individual of group support, or subjecting him to a boring monotonously repetitious stimulus-situation, or isolating him from important sensory stimuli will derange thought, judgment and behavior, inducing hallucination, panic, and paranoid suspicion and violence.⁷

(3) Clauding of Consciousness due to any of the Common Physiologic or Drug Induced Causes. In predisposed persons (i.e. with latent paranoid tendencies) almost any of the causes

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E. L. Bliss (University of Utah), Studies of Sleep Deprivation, Its Relationship to Schizophrenia, unpublished paper given at Western American Psychiatry Association meetings, November, 1957; G. Aronson, discussion of above paper, on file at UCLA Department of Psychiatry; Group for the Advancement of Psychiatry, Symposium No. 3, Factors Used to Increase the Susceptibility of Individuals to Forceful Indoctrination, New York, December, 1956.

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Symposium No. 3, loc. cit., unpublished paper by Philip Solomon (Boston City Hospital) on Sensory Deprivation given at Western American Psychiatry Association Meetings, November, 1957; G. Aronson, loc. cit.

of altered brain functioning may precipitate a psychotic state of long or short duration; for example, physical illness (such as viral influenza), head injury, ingestion of alcohol, anoxia, high G, lowered blood sugar brought about by exertion without having had breakfast, near-starvation, water deprivation, etc. The states induced by these temporary alterations of brain function are apt also to be temporary. However, recovery time for the psychotic state often lags significantly behind the recovery time necessary for the brain to return to its normal physiologic functioning.

(4) Changes in Personal Status, Degree of Responsibility, and Military Rank. This group contains the most important precipitants for the active paranoid state. The susceptible personality, sensitive to personal slights and secretly doubtful of its own adequacy to deal with responsibility, founders on any change which leads to the need for reevaluating its image of the self. Changes in marital status, a sudden turn in a love affair, becoming a parent, demotion or promotion in rank or responsibility are all potent toxins for the pre-paranoid personality.

A case from W. A. White's Insanity and the Criminal Law (MacMillan, New York, 1923, p. 108) illustrates the influence of change in rank. A 29-year-old private had done so well that he had been promoted to corporal after three months. But then a change was noted in him. He began to fall short of his previous efficiency. For a minor offense he was tried and fined \$20. He applied for transfer to another post but this was several times refused him by Captain R. He went one day to the basement, loaded his gun, put it in his pocket, and said he was going to get the soldier who had taken two dollars

from him. While he was looking for this soldier he was summoned to see Captain R. because of a report for misconduct. He told the captain he would like to resign. The captain said: "Very well, that will do, corporal. That is all." Instantly the soldier said: "No, it isn't all, Captain," drew his gun and shot him. In the ensuing struggle he also wounded two other men.

(5) Special Precipitants Associated with Nuclear Weapons.

That the likelihood of UDA among well-trained and selected personnel is small cannot be doubted. Sometimes it is even argued that the risk is nil, because many opportunities for spectacularly destructive acts in the past have never led to UDA. For example, no R.A.F. pilot bombed Buckingham Palace in World War II, no airline pilot has ever tried to crash into the White House or the Soviet Embassy. This argument is important, for it is impressive that so many spectacular opportunities for UDA were never exploited by a mentally deranged person. However, there is also an impressive number of cases where military personnel did in fact commit UDA (the above mentioned case of the homicidal corporal is one example). In recent history the effects of these acts were usually confined to a local scene, but now nuclear weapons provide the means for the most spectacular UDA of a magnitude unknown to persons who might have been similarly tempted in the past. Nuclear weapons will not only make acts technically possible that could scarcely have been dreamed of before, but they may even constitute a specific attraction for those with paranoid potentialities. In fact, in certain paranoid delusions, a

nuclear detonation may seem the ideal tool for translating the fantasies into reality. There are at least two such delusional complexes frequently present in paranoid conditions that come immediately to our mind:

"Herostratus Delusion"⁸ -- The Motive of Seeking Fame.

In the year 356 B.C. the Greek Herostratus burned the famous temple of Diana in Ephesus, which was reckoned as one of the Seven Wonders of the World. Herostratus confessed afterwards that he did this merely to immortalize his name.⁹ John Wilkes Booth, the paranoid assassin of Lincoln, was in part actuated by the same motive of seeking fame. It is conceivable that knowledge of the enormous destructiveness of the nuclear weapon may stimulate the latent grandiosity and exhibitionism present in every paranoid. For example, the Mad Bomber of New York full of pride made bombs in his home and often grandiosely boasted of his targets to be.

"Jonah Delusion" -- The Motive of a Mission in Defiance of Authority. Paranoid individuals frequently harbor the idea that they are invested with a special mission that sets them

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This term, and the term "Jonah delusion" used below, were merely introduced for the purpose of this discussion and do not refer to general psychiatric usage. Incidentally, as mentioned in Chapter II, the story of Herostratus has recently been used in Czech propaganda broadcasts about the risk of nuclear accidents.

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To frustrate this motive, the Ephesians passed a decree condemning his name to oblivion, but Theopompus mentioned him in his history.

apart from society and compels them to defy authorities and violate accepted standards. Some may feel that they received this mission from God, others set themselves even above the authority in whose behalf they pretend to act. Thus the prophet Jonah prophesized to the people of Nineveh that their city would be destroyed because of their wickedness. Then, the people "turned from their evil way" and God spared the city; "but it displeased Jonah exceedingly, and he was angry." (Jonah 4:1).

In such groups as vigilantes or the Ku Klux Klan there are often individuals who hold that they must take the law into their own hands because the authorities fail to act against the enemy. They are possessed of the double delusion that they will save the world, or a special segment of it such as a town or a race, and that the authorities are too soft, too ignorant, in secret conspiracy with the enemy, or covertly wish destruction of the enemy but are uncomfortably constrained by outmoded convention.

These importunate convictions may often be held in private thoughts or verbalized in casual conversations by those impatient with the continued existence of an enemy, or with the real or fancied weaknesses of the authorities. But it is only among paranoid persons (or others in a mob setting) that such ideas could be translated into action in violation of the normally accepted standards and discipline.

Sometimes the individual afflicted with paranoid delusions may believe that his convictions are actually in line with what the authorities secretly wish to see occur. Such an idea may serve as the nucleus for an elaborate, long-range plot.

Guiteau was convinced that the removal of Garfield was devoutly wished by the Republican Party and the republic, that the authorities were powerless, and that only assassination could bring about the nation's desire. Similarly it is possible that atrocities committed by a platoon of Israeli soldiers upon an Arab village during the Suez Campaign of 1956 (for which the platoon was later tried by the Israeli Army) were actuated by the paranoid convictions of an Israeli major that he was doing what higher command wished him to do but could not overtly order him to do.

The paranoid with a "Jonah delusion" may resemble a genuine reformer or a hero who defends his fellow men against their enemies. However, the genuine reformer is driven by the desire to better social conditions, and the destruction of an enemy is to him merely a means toward this goal, whereas the paranoid is driven by the desire to destroy the enemy, the betterment of the world remaining secondary. Jonah was not pleased that the people of Nineveh had "turned from their evil way;" he was angry to be deprived of his mission to destroy. And the true hero, while he may seek fame much as Herostratus did, will do it within the norms approved by society instead of through a negative destructive act. Both the hero

and the reformer seek validation and accept compromise within the society they wish to reform or defend, but the paranoid accepts himself as being isolated from his society and as moving within his delusional, secret mission.

2. Disorders of Impulse Control

This is a rather heterogeneous group of disorders which offers some difficulties in classification but no major difficulties in description. Terms that have been used, and are still in use, to categorize persons in this group are: constitutional psychopathic inferior, psychopath, perverse personality, impulsive personality, neurotic character, infantile character, kleptomania, pyromania, etc. Generally the individuals falling into these categories may be grouped together according to the Standard Nomenclature¹⁰ under Antisocial Reaction (000-x61), Emotional Instability Reaction (000-x51), Passive-Aggressive Personality--Aggressive Type (000-x52), Personality Trait Disturbance--Infantile Personality (000-x5y). The Army also uses the terms Pathologic Personality and Immature Personality in addition to some of the terms already in the Standard Nomenclature.

Generally such people do not harbor plans over a long period of time such as the paranoid will -- with the notable exception of the pyromaniac. Consequently they may pose a great problem for detection unless their life histories are thoroughly gone into in the course of psychiatric examination.

¹⁰

Op. cit.

a. Characteristic Acts. Senseless destructive acts, in civil and military life, are frequently caused by such impulse-ridden people, but usually do not have the magnitude or scope of the destructive acts brought about by the paranoid group. For instance, none of the assassins, successful or not, of Presidents would fall into this diagnostic category; but many of the people who commit such acts as pulling a grenade pin "to see what would happen" are impulse-ridden.

The Bureau of Ordnance, Department of the Navy, published a collection of case histories of casualties that have occurred in the handling and use of ordnance equipment and ammunition.¹¹ Among these cases the following destructive acts have apparently been performed by such impulse-ridden or infantile personalities. (We would assume that similar collections could be made from the ordnance experience of the other two services.)

On August 3, 1944, an assistant cook improperly obtained a charge of TNT in order to blast fish. He lighted it with a cigarette. As he was examining it to make sure it was ignited, the explosion took place. The man was blown to pieces. (Case II-14)

On August 11, 1944, during a training exercise, a Marine private found a whistle bomb which had failed to explode. He ignited it with his cigarette lighter. The bomb burst in his hands, blowing off the tips of two fingers. (Case II-16)

On May 16, 1929, grenades issued for patrol were ordered to be turned in afterwards. A Marine enlisted man failed to comply with these instructions. He kept one live grenade and one dummy grenade. Later, in an attempt to frighten other Marines, he pulled the pin of what he thought was the dummy grenade. He was severely injured. (Case II-18)

On April 23, 1945, an aviation machinist's mate third class was guarding 20-millimeter lockers as sentry. Contrary to orders, he removed a round of ammunition and attempted to disassemble it. Somehow, he caused the nose fuze to detonate and the projectile to explode. He died from the injuries. (Case II-20)

Four people were injured on April 23, 1944, when the following UDA took place, according to testimony: "Private B and I each found a rifle grenade. We carried them back to our tent. Private K told us that we had better not fool with the grenades and to get rid of them. Private B said, 'What will happen if I pull this pin?' Then the grenade exploded." (Case II-23)

On December 20, 1943, a working party from a destroyer went into a magazine at a naval ammunition depot to obtain ammunition. An explosion occurred which injured two people, but luckily was not communicated to other ammunition in the magazine. According to the testimony of a fireman third class: "It was all my fault. The gunner's mate told me there was some French ammunition in the magazine, and I wanted to see it. I picked up a fuze out of a tin box and handed it to P asking him what it was, and he said he didn't know. Then I told him, 'Hell, I'll find out,' and I pulled the wire out. It started to smoke, and I pushed the wire back in and then it exploded." (Case II-25)

On June 15, 1945 a coxswain picked up an Japanese antipersonnel bomb dud from an abandoned bomb disposal area, which was clearly marked. The coxswain had had long and extensive training, and had been warned and lectured time and time again not to pick up, handle, or possess any enemy bomb duds. Nevertheless, he took a dud to camp and attempted to take it apart in a crowded spot. Unable to disassemble the bomb

quickly he threw it to the ground twice. Several others warned him that the bomb might be dangerous and told him to get rid of it. The coxswain threw it down a third time. It exploded, killed 1 and injured 13. (Case II-30)

A Marine found a 37-millimeter dud and turned it in to the Quartermaster tent. Later, a sergeant came into the tent and saw the dud. In disregard of orders and safety, he aimed the shell at a hole in the wooden floor of the tent and dropped it. He commented that he would make 'a pretty good bombardier.' He dropped the shell at least six times. Finally, inevitably, it exploded. The sergeant was killed and 2 others were injured. (Case VII-10)

At a Marine Scout Bombing Squadron base several men were in the gunner's ready room. A sergeant approached another sergeant and asked him if he wanted to play Russian roulette. The first sergeant then handed his revolver to the second sergeant and urged him to fire. The second sergeant looked to see if the gun was empty. With the remark 'that's cheating,' the first sergeant snatched the gun, and -- unknown to the other -- inserted a cartridge. He gave the gun back and again told the other to fire at him. In jest, the second sergeant aimed the revolver and pulled the trigger. The first sergeant was killed. (Case VIII-11)

At a naval air station, a sentry withdrew his revolver and emptied it of cartridges. He pointed the gun at different objects, snapping the trigger. Others warned him not to play with the gun. Then he inserted one cartridge, spun the cylinder, snapped it shut, placed the revolver to his head and pulled the trigger. He died about an hour later. (Case VIII-12)

A similar kind of UDA which is usually due to such disorders of impulse control is well known in Air Force experience. This is the unauthorized take-off in a plane by an officer or enlisted man unqualified to fly the plane, and usually resulting in a crash. A recent example occurred in June, 1958, when

a mechanic took off in a B-45 at the SAC base at Huntington, England, terminating his unauthorized flight in a crash landing.

b. Motivation for Destructive Acts. It is perplexing to assess the motivation prompting such acts. Generally, one can say that countless fatal and near-fatal "accidents," such as those above, are the results of braggadocio; desire to show off one's own fearlessness, skill, or knowledge of the weapon; or the kind of curiosity which does not quite believe the consequences of one's own acts (e.g. that grenades detonate after the pin is pulled).

Resentment toward superiors, a variety of childish conceit, is often seen in some impulse-ridden characters. This resentment may lead to destructive acts against one's employer or superior (setting fire to employer's store or office, inserting explosive device under carburetor of supervisor's car, etc.), or may lead to such carelessness and lack of vigilance that a destructive accident will result. When resentment and vengefulness are powerful motives in shaping a long-range plan against a person or persons important in the individual's life, they usually indicate a paranoid rather than an impulse-ridden personality.

c. Soft Signs of the Impulse-Ridden Personality. Although many impulse-ridden personalities apply for service in the Armed Forces, they are for the most part easily screened out initially or by the rapid appearance of their immaturity and

impulsivity under discipline and regular routine. However a hard core of such personalities may not show flagrant evidence of disorder consistently or intensely enough to make for early detection. Hence it is necessary for physicians senior commanders to become familiar with the "soft" signs the minimal cues, of the impulse disorders. Again, it must be pointed out that these signs are seen normally in many individuals and only their preponderance, association, together, duration suggest the immature personality disorder of impulse control.

The soft signs of the impulse-control disorders:

Persistent boyishness and "infectious charm"

Naivete and "innocence," a kind of wide-eyed wonder and awe which is largely put on for the purpose of impressing colleagues and superiors with one's sincerity.

Readiness to gossip with great excitement and interest in disasters, catastrophes, etc.

Glib explanations with smooth, plausible persuasiveness -- a pseudo-readiness to admit one's error.

Attempts to play off one group of peers against another, sometimes attempting to align oneself in favor with authority.

Shallow loyalties to friends, shifting rapidly toward those with power and wealth. Rarely have solid "buddy"-relationship.

Frequent job changes or request for job changes, using plausible but actually petty and flimsy reasons for moving on.

Temper outbursts over trivial causes, sometimes disarmingly explained away.

Sullen irritability, becoming easily bored and restless, craving change and excitement.

A certain "show-offishness" coupled with petulance should someone else be temporarily holding the center of the stage.

Generally, this group of people serve poorly in civil and military life. However, under special circumstances of intense excitement, heightened interest, or imminent catastrophe they may function temporarily well and, at times, heroically. Often such people seek jobs as firemen or in what they consider to be the exciting, or helter-skelter, divisions of the police department -- e.g. the vice squad. Dangerous weapons appeal; and foolhardy behavior with such weapons sometimes occurs in the history of the impulse-ridden personality.

d. Precipitants for Overt Destructive Action by Impulse-Ridden Persons. UDA by these people may result from widely variable precipitants. It may occur like an unpremeditated "accident," the by-product of a rash act whose consequence was not foreseen; or may be the fruit of ill-tolerated tension, an attitude of "what-the-hell-let's-get-it-over-with." To bring about such an act, tenuously held controls over impulsive discharge must give way. The following precipitants, as in the paranoid state, may temporarily abrogate impulse control:

Sleeplessness;

Social isolation, prolonged boredom, and sensory deprivation;

Clouding of consciousness due to any of the common physiologic or drug-induced causes (particularly alcohol);

Changes in personal status, degree of responsibility, and military rank, particularly when the individual has been downgraded or lost favor with some powerful friend or authority.

The presence of an admiring or taunting group may also induce or provoke the individual with weak impulse control to show-off or to take dares. Ordinarily he may retain enough control and awareness of the consequences to resist his own impulses. However, unlike the paranoid who is not so readily moved by requests to show off, the immature personality may be stimulated to rash action by such invitations, taunts, or dares.

Special precipitants or excitants associated with nuclear weapons: The tremendous power of nuclear weapons and their instantaneous manifest effect are not major excitants to the paranoid personality, who is more interested in the far-reaching consequences of UDA -- e.g. immortalizing his name or ridding the earth of evil. Not so with the impulse-ridden personality: he is attracted by the holocaust itself or by the mechanism (machine, bomb, personnel) which brings about the holocaust or seeks to end it (e.g. fire engines). The longer-range consequences dwindle into insignificance as he moves impulsively (or even with a degree of calculated planning)

to bring about a sight, sound or drama of actions that will fill him with a sense of excitement, adventure, and power.

Pyromania (pathological firesetting as distinguished from arson which is for profit) offers a parallel model to the type of situation conjectured above. Although pathological firesetters may vary in their diagnostic grouping (mental defectives, psychotics, "thrill seekers," vengeful and spiteful persons, etc.), many are motivated by the desire to see the tangible result of their own power as it brings about a visual holocaust. They may plan for months, unlike most impulse-ridden personalities, to obtain jobs in hospitals, schools, etc. where the result of a fire -- the fire itself, the fire-fighting apparatus, the people streaming out of buildings -- is greater than in the ordinary business establishment or residence. They may even obtain jobs as firemen in order to gain proximity to fires and to the means of setting fire and quenching it. Occasionally firebugs who seek to join the fire department or individuals who wish to be policemen or detectives are actuated by the desire to participate in the control of impulses which they fear may erupt within themselves.

Curiosity as to the workings of a powerful mechanism (a weapon, police force, etc.) in the precipitation or termination of a holocaust is sometimes a motive in those who join fire-fighting or police forces. It is conceivable that an impulse-ridden personality, who is curious to see the mechanism of a weapon or social institution in action, and who suffers

the boredom of inaction or the rising tension of a crisis, may commit the act triggering his organization into performance of those duties he had been so curious and fascinated to see.

3. Miscellaneous Temporary States

a. Psychomotor Epilepsy. Psychomotor epilepsy (000-550 -- acute brain syndrome associated with convulsive disorder) is characterized by acute episodes of seemingly well-coordinated behavior, lasting from several seconds to 15-30 minutes, in a setting of diminished awareness of external stimuli and, hence, potentially inappropriate to a changing situation. Usually the individual has no memory afterward for his "automatic" behavior. This behavior is the equivalent to the muscular convulsions or sudden loss of consciousness seen in other forms of epilepsy (e.g. grand mal and petit mal). In effect, just as the muscular convulsion results from a paroxysmal discharge in certain portions of the brain, the psychomotor behavior pattern with its relatively high degree of coordination results from paroxysmal discharge in certain other specific parts of the brain. Some 50 per cent of all persons with epilepsy suffer psychomotor seizures mixed with other forms of seizure patterns. The number of people suffering psychomotor seizures uncontaminated by any other form of seizure is difficult to estimate because of the relatively "normal" aspect of the psychomotor seizure-pattern. In a sample of military

patients with epilepsy, 6 per cent were diagnosed as psychomotor epilepsy;¹² this rate would yield about 5 per 100,000 (enlisted) men per year.

The type of action observed in psychomotor seizures may vary widely. Of interest here are the unmotivated fit of rage, the continuation of a previously begun action even when the external situation would dictate shifting to another form of action, or the disruption of smoothly purposeful conscious action by action which is not under conscious control and not quite so smoothly coordinated.

A man driving down a busy city street crashed into the rear of another car and then drove on. He paused at a light, started again at the green signal, crashed into another car, and again drove on. He drove with fair coordination, observed traffic signals, and did not attempt to evade detection. When halted by the police several blocks from his second accident he was mildly confused and professed amnesia for the collisions. Review of his past history and brain examinations confirmed the diagnosis of psychomotor epilepsy.¹³

A 39-year-old successful teacher, whose hobby was a selective record collection, went into a large store looking for unusual interpretations; at that point his memory failed. He stole an inferior record that he would never have bought and rapidly left the store. When stopped, he fought and fled.

12

H. S. Colony and B. I. Kahn, "Military Aspects of the Diagnosis of Epilepsy," U.S. Armed Forces Medical Journal 4 (1953), pp. 1412 - 1415.

13

Case supplied by Nicholas Bercel, M.D., Los Angeles.

Review of past history, coupled with brain wave studies, indicate that the theft --- a well-coordinated but poorly motivated action -- is more properly considered as a psychomotor epileptic act rather than an act of kleptomania.¹⁴

Rarely, but still of importance because of the danger involved, one sees cases of epileptic furor. This is a class of epileptic phenomena contiguous but not identical with psychomotor epilepsy. In epileptic furor, the apparently unmotivated tremendous rage destroys anything and everything in its path, in an episode which may go on for hours. Usually such furors are seen in deteriorated epileptics; but they may occasionally herald an hitherto unsuspected convulsive state.¹⁵

It is rare to find a person of military age who suffers a convulsive state without a history of previous epileptic episodes. However, if for one or another reason the inductee wishes to conceal his past history of psychomotor or other epileptic phenomena, neither physical nor cursory psychiatric examination is likely to disclose the convulsive state or its history. Fortunately, electroencephalographic examinations (EEG, brain wave) in the waking state detect 35-50 per cent of those with psychomotor epilepsy; if the EEG is taken during sleep, the rate of detection rises to 85-95 per cent.

14

Case described by L. Massion-Vernlory and L. Casslers, "Un cas de vol comme equivalent epileptique, Acta Neurol. et Psychiat. Belg., 58:186-193, February 1958.

15

A case is described in Edward A. Strecker, F. G. Ebaugh, and J. R. Ewalt, Practical Clinical Psychiatry, Blakiston, Philadelphia, 1951, p. 121.

b. Pathological Intoxication. This is an acute behavioral disturbance (000-3312.x1 -- acute brain syndrome, alcohol intoxication, with psychotic reaction) occurring within a few minutes of ingesting alcohol in large or small amounts. The behavior itself lasts from minutes to half an hour and may take many forms: excitement, furor, confused agitation, a twilight state similar to sleep-walking with smoothly coordinated but automatic behavior, a mistaking of the situation with a panicky assumption that the worst has happened, etc. Here too, as in psychomotor epilepsy, the behavior of the individual up to the time of his "spell" may seem quite normal to the viewer, and the abnormal action itself may be very well coordinated, leading to destructive results that would be unattainable by a disjointed flailing-about.

In the main body of the report, on page 25, an episode is detailed of pathologic intoxication, which led to the over-powering of a guard at a weapons storage.

At a recent sales convention several men were chatting at the bar. Another salesman approached amiably only to be met by a sudden, highly effective physical onslaught from one of the group. The assailant, up to the moment of the approach, had been laughing and talking in an unremarkable manner and had not shown any effect from the one Scotch he had imbibed. He claimed amnesia for the assault -- as is invariably the case in instances of pathological intoxication. It is not known whether the onslaught was related to any specific connection between the assailant and his victim. Generally, however, the behavior of the person suffering pathologic intoxication bears the unmistakable mark of his fears, hopes, hates, and loves and, hence, is not wildly indiscriminate.

Once an individual has had a bout of pathological intoxication the probability of his having another are much greater than that of a person who has never had an episode of pathological intoxication. Hence past history can be exceptionally of value in detecting those individuals likely to suffer this syndrome. However, if previous history of such episodes is concealed, no diagnostic method will succeed in uncovering this disorder before it again recurs. Some authorities believe that test doses of alcohol may be of use diagnostically in provoking pathological intoxication under examination.

c. Fugue States. Fugues (000-x02 -- dissociative reaction) must serve as a wastebasket term for those episodes of gross personality disorganization which are sudden in onset, temporary in duration (minutes to months), and are unrelated to schizophrenia, epilepsy, ingestion of alcohol or other drugs. For the most part the fugue states are related to the so-called hysterical group of disorders. This means only that the individual has served as a respectable, fairly productive member of society while at the same time suffering a neurotic conflict which he had kept from the view of others and from his own awareness. The conflict brought into consciousness by fatigue, unusual stress, or a sudden shift in important interpersonal relationships, must be suppressed, disavowed, or frozen. A fugue state then results: aimless running,

repetitive action, complex trains of action with amnesia, sleepwalking, paralysis of action, etc.

On June 22, 1893, in broad daylight, the Mediterranean flagship of the British Navy was sunk as a result of collision. The Commander-in-Chief ordered two columns of ships to turn inwards, in a standard naval maneuver, in spite of the fact that the ships were not far apart enough to accomplish the maneuver safely. The Admiral, Sir George Tyron, was warned of the impending collision by one of his officers but seemed to have a temporary absence of mind. He did nothing and did not seem to acknowledge the warning given him. After the collision the Admiral was heard to say: "It was all my fault." He drowned with part of his crew.¹⁶

An electrical engineer of considerable ability was referred for examination by his corporation because of a very embarrassing episode. He had suddenly left some delicate experimental work in the laboratory and entered a clerical room, apparently engrossed in deep thought, and then approached one of the stenographers as if to attack her. But he vigorously and persistently denied this, although he was unable to assign a reason for being away from his laboratory. It developed, however, that on numerous other occasions he had suddenly dropped his work for a few seconds and indulged in queer purposeless stunts.¹⁷

16

Frank Lipscomb, "The Victoria and the Camperdown," U.S. Naval Institute Proceedings, January 1958, pp. 53-61.

17

Karl A. Menninger, The Human Mind, A. Knopf, New York, 1946, p. 239. This fugue may have been due to psychomotor epilepsy.

Some cases of pilot error are perhaps also due to mild fugue states. Sometimes pilots fail to respond adequately to a clearly defined stimulus situation in spite of the fact that all of the necessary cues are present for a proper response and the proper procedure is well known to the pilot. These fugue-like states may be due to the tendency, intensified during stress, to shut out new external stimuli and to freeze action temporarily until control can be re-established.

A pilot reporting a near accident: When you reach the point where you turn on base leg for landing, I started reducing power. The horn started to blow and I realized something was not as usual. I had let down to 200 feet before it occurred to me that the warning could be the one thing I had forgotten.¹⁸

Another pilot reported: On a gunnery hop I became fascinated with the tow on one of my overhead runs. I concentrated hard on trying to hit the target and soon lost all sense of anything else. . . It was sort of like a semi-coma. My flying the plane was completely automatic, so much so that I don't remember much of what I did on the run.¹⁹

In addition, there are of course many forms of physiological stress which can produce temporary states of mental confusion or loss of full consciousness. Of importance in flying is the so-called oxygen paradox: if a person in an anoxic state suddenly takes in oxygen, a profound temporary

¹⁸

B. Clark, M. A. Nicholson, and A. Graybiel, "Fascination: A Cause of Pilot Error," Journal of Aviation Medicine, October, 1953, pp. 429-440.

¹⁹

Ibid., p. 434.

disturbance of the central nervous system may result, leading to mental confusion.²⁰ Furthermore, G- stress may also cause temporary mental confusion.

C. THE PREVENTION OF UNAUTHORIZED DESTRUCTIVE ACTS

Of the syndromes discussed as possible sources for UDA -- the paranoid group, the impulse-disorder group, and the miscellaneous group (epilepsy, pathologic intoxication, and fugue states) -- the paranoid group has the highest potential for bringing about a serious UDA. The impulse-disorder group might contribute, as in civil life, more frequent destructive actions but of a less deliberately destructive character. It is conjectured, because of the relative dimming of consciousness in the miscellaneous group, that UDA among this group would be minimal were UDA to require highly complex, smoothly organized patterns of action.

The prevention of UDA must take into account the characteristics of each of these groups. It is suggested that prevention of UDA be accomplished by several interlocking means:

- (1) Screening Procedures
- (2) Supervision
- (3) Prevention of precipitants to deranged behavior
- (4) Technical arrangements

²⁰F. Latham, "The Oxygen Paradox. Experiments on the Effects of Oxygen in Human Anoxia," Lancet, V. 260 (1951), pp. 77-81; and R. Grandpierre and C. Frank, "The Paradoxical Action of Oxygen," Journal of Aviation Medicine, V. 23 (1952), pp. 181-185.

1. Screening Procedures

Selection and screening procedures are designed to prevent the wrong people from obtaining a certain job ("negative selection"), or to choose the right people for a particular task ("positive selection").

Ordinary Pre-Induction and Induction Screening Procedures with their routine psychiatric examinations screen out the bulk of those people who are overt paranoids or schizophrenics and, to some extent, can detect a paranoid personality at the point of decompensation, i.e., the transition to the more overt phase of the disorder. However, since people with paranoid personalities or lurking paranoid states can often skillfully dissemble and pass as normal, more complete examination may be desirable when considering an applicant for a position where UDA could be singularly catastrophic. In regard to the group of impulse disorders, those men who are highly motivated to enter the military service would have little difficulty slipping through the initial screening net. The miscellaneous group, if similarly motivated, could also escape detection at this point.

A Special Psychiatric Examination by a competent psychiatrist would comprise several hours of interviewing, observing, and musing about the individual examined. Necessary for a thorough examination are: review of the individual's life history with special emphasis on the nodal points of his development and his reaction to the crises of everyday life,

scrutiny of his motivations for particular kinds of jobs or situations, and assessment of his current mental status.

Psychological Testing could be effected with a battery of tests (the backbone of which are the Wechsler-Bellevue, the Rorschach, and the Thematic Apperception Tests) and would take several more hours in addition to the special psychiatric examination. All but the most skillful of dissemblers among the paranoid and impulse disorder groups will be detected by the Psychiatric Examination combined with the Psychological Testing. Those with pathologic intoxication or psychomotor epilepsy would be able, without too much difficulty, to evade detection were they to conceal the specific relevant data of their past histories (i.e. the reaction to alcohol, episodes of past seizures). Careful psychological testing might be able to pick up those individuals likely to suffer fugue states although this is difficult to be certain about because of the wastebasket nature of the term "fugue."

Electroencephalography (brain wave tests) is a relatively simple procedure from the point of view of time -- given the technician to take the recording, the machine to make the record, and the electroencephalographer to interpret the record. A waking record can be taken in 15 minutes; such a record will detect 35-50 per cent of those with psychomotor epilepsy and a greater proportion of those with grand mal and petit mal epilepsy. Another hour of recording while the subject is asleep increases the detection rate to 85-90 per cent

of those with any convulsive disorder. Electroencephalography is useless in the detection of the other disorders considered in this Appendix.

Isolation -- Sensory and Social is a special technique which may, with more validation, be turned to use as a screening device. Only between one-third and one-quarter of "normal" volunteer-subjects are able to withstand for more than several hours being alone in a chamber without sensor stimuli impinging upon them. It is conjectured that those who are not able to tolerate this situation for any length of time may suffer more readily precipitated derangement than those who are able to tolerate it. To heighten the potency of the sensory isolation situation as an experimental precipitant, sleeplessness and small doses of an hallucination-inducing drug (e.g. LSD) may be added. It is unlikely that the epileptic group would be detectable by such means. Again, the experimental, unverified nature of this procedure must be emphasized.

The combination of a special Psychiatric Examination, Psychological Testing, and perhaps Sensory Isolation would make for quite effective screening. However, it could only be used for "positive selection," that is to select a few, especially well suited men out of a large group. It would be too cumbersome, and perhaps even objectionable, if these procedures were applied to a large segment of the military personnel. Furthermore, since the discriminating indices are still rather uncertain it would be necessary that people could

be selected without concern about those who are left out. In contrast, for screening procedures that have to be applied to a wider group, such high rejection rates for doubtful reasons are undesirable.* Hence we would envisage that these special procedures could be used only for a few, especially critical duties.

2. Supervision, Psychiatric Reassessment, and Alertness of the Medical Officer and Senior Commanders

Continuous supervision and reassessment would also be necessary for the most critical duties, not only because a few dangerous people might inevitably have slipped through the selection procedures, but more importantly because of those who will develop a mental disorder during the course of duty, months or years after the initial screening. This reassessment could be particularly useful for those disorders which reveal themselves best in ordinary social contacts and job performance, where the individual is not constantly on his good behavior as he may be during screening procedures. This would apply to the impulse disorders, pathological intoxication, psychomotor epilepsy, and to a lesser degree also to paranoid disorders.

* See also Chapter IV, B, 3, in the main body of this report. The greater percentage error in predictions of psychiatrically unsatisfactory performance as compared with satisfactory performance is also shown in Albert J. Glass and Francis J. Ryan, "Psychiatric Prediction and Military Effectiveness," U.S. Armed Forces Medical Journal, 7 (1956), pp. 1427-1443, 1575-1588; 8 (1957), pp. 346-357.

3. Prevention of Precipitants to Deranged Behavior

There are a number of precipitants that can trigger off UDA in people with lurking mental disorders: anoxia, alcohol, drugs, sleeplessness, low blood sugar after skipping a meal, boredom, changing interpersonal situations, changes in the authority structure, etc. In ordinary military activities these precipitants cannot be avoided. However, for a few critical duties some of these precipitants could be reduced through administrative control and supervision: e.g. alcohol ingestion, sleeplessness, drugs, boredom.

4. Technical Devices

Technical devices constitute the most promising, and by far the most feasible measures against UDA. Therefore, several such measures have been suggested in the main body of this report (Chapter IV, B). Essentially, they have to provide either of two protective features: (1) restrict the capability for destructive action to higher command levels; (2) require collaboration for destructive action by two or more persons on the same (lower) level. The safety gained by the first type of measures is clear, here the assurance lies in the seniority and selectness of the persons who control higher command levels. It is important, however, that the restrictions do in fact confine the capability to initiate destructive action to the senior persons only, and exclude less selected lower rank personnel who might be located at the higher commands.

The safety gained by the second type of measures requires further examination. In case of fugue states, psychomotor epilepsy, or a bout of pathological intoxication, the advantages gained by a technical requirement for collaboration of lower level personnel are obvious. It is highly unlikely that an individual suffering one of these temporary disorders could carry out a misperceived, hallucinated, or delusionally conceived order if he had to convince a colleague to perform a complementary act to complete destructive action. The colleague would recognize, with little difficulty, the derangement.

However, in the paranoid and impulse control disorders the situation may not be so simple. Both paranoids and psychopaths may be extraordinarily persuasive; there may even be the unfortunate concatenation of two paranoids, two psychopaths, or a paranoid personality and a passive, suggestive person (e.g. Leopold and Loeb). It is by no means certain how large the number of persons necessary for collaboration should be in order to avoid UDA. In all probability, a four-person group would be "safe" in the sense of being immune to a paranoid or impulsive member; in the case of a three-person group acting conjointly before any destructive effect could occur, the possibility of the third person being a prize in an argument between two principal antagonists becomes a danger. Care must of course be taken that this particular safeguard -- group distribution of control over hazardous devices -- does not become a retardant to authorized destructive action.

5. Summary

The relative effectiveness of the means for preventing UDA from mental disorders may be rated as follows:

- nil: without appreciable effect against the specified mental disorder
- poor: ineffective against an appreciable percentage of persons with specified disorder
- fair: may prevent most UDA from specified disorder without, however, making the risk negligible
- safe: will make the risk from specified mental disorder negligible

RELATIVE EFFECTIVENESS OF PREVENTIVE MEANS

	Ordinary Screening	"Positive Selection"			Super-vision	Pre-vention of Preci-pitants	Techni-cal Devices
		Psychi-atric Exam. & Psychol. Test	EEG (in sleep)	Sensory Isola-tion			
Paranoid	poor	fair	nil	fair	fair	poor	fair to safe
Impulse Disorder	poor	safe ?	nil	fair ?	fair	fair	fair to safe
Psychom. Epilepsy	nil *	poor	safe	nil	?	?	safe
Pathol. Intoxicat.	nil *	poor	nil	?	fair	safe	safe
Fugue State	nil *	poor	nil	fair	nil	?	safe

* Assuming the inductee conceals his disorder or does not know he has it.

Appendix II
STATISTICAL PROBLEMS
By Albert Madansky*

1. INTRODUCTION

If an object has probability θ_1 of failing a first test, θ_2 of failing a second test, etc., and if failure on the i -th test is independent of failure on the j -th test for all $i \neq j$, then the probability of failing all r tests is

$$\theta = \prod_{i=1}^r \theta_i.$$

The natural way to estimate θ would be to submit a large number n of objects to all of the tests. Of these, t would fail them all, and t/n would be the usual estimate of θ . This procedure has the practical advantage of not using the assumption that the tests are independent.

Let failure of the i -th test correspond to failure of the i -th safeguard on a nuclear weapon, and assume that a nuclear accident occurs if and only if all r safeguards fail on a given weapon. It is doubtful that failure of the i -th safeguard is independent of failure of the j -th safeguard for all $i \neq j$ in this case. However, we make this assumption and exploit it because in this case we have $t = 0$ and n is not large enough.

* L. J. Savage's help in the formulation of these ideas is gratefully acknowledged.

to ensure that θ is negligible. For example, if $n = 100$, we are 90% confident that θ is bracketed by 0 and 0.023, and $\theta = 0.023$ is not a negligible value of θ in our context.

We therefore wish to consider the following problem. Let X_1, \dots, X_r be independent and binomially distributed from samples of known sizes n_1, \dots, n_r and with unknown parameters $\theta_1, \dots, \theta_r$. We wish to estimate

$$\theta = \prod_{i=1}^r \theta_i.$$

Since x_j , the number of observed failures of safeguard j , is very small compared to n_j , the number of "exposures" to such failure, we may make the Poisson approximation to each of these binomial distributions, where $\lambda_j = n_j \theta_j$ is the parameter of the j -th Poisson distribution. Our problem, then, is to estimate

$$\theta = \frac{\prod_{i=1}^r \lambda_i}{\prod_{i=1}^r n_i},$$

which reduces to the problem of estimating

$$\phi = \prod_{i=1}^r \lambda_i.$$

We define

$$\begin{aligned} B(x | \theta, n) &= \Pr\{X_1 = x_1, \dots, X_r = x_r | \theta_1, \dots, \theta_r, n_1, \dots, n_r\} \\ &= \prod_{i=1}^r \binom{n_i}{x_i} \theta_i^{x_i} (1 - \theta_i)^{n_i - x_i}, \end{aligned}$$

which is approximated by

$$\begin{aligned} P(x | \lambda) &= \Pr\{X_1 = x_1, \dots, X_r = x_r | \lambda_1, \dots, \lambda_r\} \\ &= \prod_{i=1}^r \frac{e^{-\lambda_i} (\lambda_i)^{x_i}}{x_i!}. \end{aligned}$$

2. POINT ESTIMATES OF THE PROBABILITY OF AN ACCIDENT

The maximum-likelihood estimate of θ is

$$\hat{\theta} = \frac{\prod_{i=1}^r x_i}{\prod_{i=1}^r n_i},$$

which is also the minimum-variance unbiased estimate. We shall use this estimate henceforth, but wish now to catalogue other possible estimates.

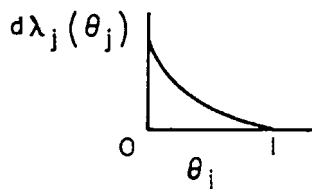
Let us pretend that a priori the θ_j 's are independent and that θ_j has probability distribution $\mu_j(\theta_j)$, $j = 1, \dots, r$. It is well known that if one wishes to estimate θ_j by an estimate $\delta_{\lambda_j}(X_j)$ based on the random variable X_j and if the loss function is the squared error $[\delta(x_j) - \theta_j]^2$ when we observe $X_j = x_j$, then the estimate that maximizes the expected loss, given $\{\mu_j(\theta)\}$, is

$$\delta_{\mu_j}(x_j) = \frac{\int_0^1 \theta_j B(x_j | \theta_j, n_j) d\mu_j(\theta_j)}{\int_0^1 B(x_j | \theta_j, n_j) d\mu_j(\theta_j)} .$$

For various choices of $\mu_j(\theta_j)$ we can obtain $\delta_{\mu_j}(x_j)$, and hence obtain

$$\prod_{j=1}^r \delta_{\mu_j}(x_j)$$

as an estimate of θ . It may be reasonable to assume that $d\lambda_j(\theta_j)$ has the following general shape for each j :



One such $d\lambda_j(\theta_j)$ is $d\lambda_{m_j}(\theta_j) = (m_j + 1)(1 - \theta_j)^{m_j} d\theta_j$, where $m_j \geq 0$ is chosen so that the rapidity of decline of $d\lambda_j(\theta_j)$ as θ_j increases corresponds with "intuition." For this choice of $d\lambda_j(\theta_j)$, we have

$$\delta_{\lambda_{m_j}}(x_j) = \frac{x_j + 1}{(n_j + m_j + 2)} .$$

Another way of interpreting m_j , then, is the following.

Given that X_j based on n_j observations is zero, $\delta_{\lambda_{m_j}}(0)$ tells us to estimate θ by saying that "for sure" we will observe one failure in the next $m_j + 2$ trials. Then m_j is chosen so that one is (subjectively) willing to make such a statement. In particular, if $m_j = 0$, $d\lambda_j(\theta_j) = d\theta_j$ (i.e., θ_j has an a priori uniform distribution) and $\delta_{\lambda_0}(x_j) = (x_j + 1)/(n_j + 2)$, a result first developed by Thomas Bayes. (This estimate is used in an analogous context by Reed [5].)

Another $d\lambda_j(\theta_j)$ that has the foregoing general shape, but where $d\lambda_j(1) \neq 0$, is the truncated exponential density

$$d\lambda_{j_{\text{exp}}}(\theta_j) = \frac{e^{-\alpha_j \theta_j} d\theta_j}{\int_0^1 e^{-\alpha_j \theta_j} d\theta_j},$$

where α_j is chosen in the same manner in which m_j is chosen above. It seems reasonable to assume a priori that in our context we have $d\lambda_j(1) = 0$. However, for completeness we record that

$$\delta_{\lambda_{j_{\text{exp}}}}(x_j) = \frac{x_j + 1}{\alpha_j} + \frac{\left[\sum_{i=0}^{n_j - x_j} (-1)^i \binom{n_j - x_j}{i} \Gamma(\alpha_j, x_j + 1 + i) \right] - \left[e^{-\alpha_j} \alpha_j^{x_j + 1} (1 - \alpha_j)^{n_j - x_j} \right]}{\alpha_j \sum_{i=0}^{n_j - x_j} (-1)^i \binom{n_j - x_j}{i} \Gamma(\alpha_j, x_j + 1 + i)},$$

where $\Gamma(\alpha, p) = \int_0^\alpha x^{p-1} e^{-x} dx$.

Finally, we can look for the worst possible $d\lambda_j(\theta_j)$ with

respect to the above loss function and find an estimate, $\delta^*(x_j)$, that will minimize our expected loss with respect to this $d\lambda_j(\theta_j)$. This estimate, first discovered by Herman Rubin, is

$$\delta^*(x_j) = \frac{\sqrt{n_j}}{1 + \sqrt{n_j}} \frac{x_j}{n_j} + \frac{1}{2(1 + \sqrt{n_j})}.$$

When $x_j \neq 0$ for all j , we are satisfied with $\hat{\theta}$ as an estimate of θ . If, however, $x_j = 0$ for at least one j , then $\hat{\theta} = 0$ and we are unwilling to use this as an estimate of θ . Unlike the case where we are willing to say that the probability is zero that the sun will not rise tomorrow given that it has risen every day in the past, in our context we believe that the probability of a nuclear accident is not zero even though we have not had one in the past, and that the probability of a given safeguard failing is not zero even though it has not yet failed. It is because of this belief that we have investigated other point estimates of θ_j , all of which are not zero when $x_j = 0$.

Another proposed estimate when $x_j = 0$ in a sample of n_j is $1/(n_j + 1)$; for if one were to take one more observation, he would estimate θ either by 0 or by $1/(n_j + 1)$, so that $1/(n_j + 1) \geq$ [the maximum-likelihood estimate based on $n_j + 1$ trials]. Using $1/(n_j + 1)$ as an estimate of θ can be interpreted as saying, "We have had no failures up to the present, but we will have a failure next time." When $x_j = 0$,

we see that for $n_j > 5$ we have $\delta^*(0) > 1/(n_j + 1) > \delta_{\lambda_0}(0) > \delta_{\lambda_1}(0) > \delta_{\lambda_2}(0) > \dots \geq \hat{\theta} = 0$, and it is a subjective choice as to how large an estimate of θ one wishes to use if one does not wish to use $\hat{\theta}$ in this case.

Berkson [1] uses $1/(2n_j)$ as an estimate of θ_j when $x_j = 0$, "an old 'empirical' rule," the origin of which he does not know, and is "quite satisfied" with it in minimum logit χ^2 estimation. He feels that when $x_j = 0$, "it seems reasonable to set $\hat{\theta}_j$ halfway between 0 and $1/n_j$, that is, at $1/(2n_j)$ " [notation ours]. Still another "empirical" rule is given by Gaddum [4]. We do not wish to utter dictum at this point, but feel that in our context we have some intuition as to the shape of the a priori distribution of θ_j and so should make use of this in preference to working rules taken from other contexts.

3. PROBABILITY DISTRIBUTION OF NUMBER OF FUTURE ACCIDENTS

If we observe $x_j > 0$ accidents in n_j trials, our estimate of the expected number of accidents in N future trials is

$$N \prod_{j=1}^r \frac{x_j}{n_j},$$

and our estimate of the probability of at least a accidents in N future trials is

$$\sum_{i=a}^N \binom{N}{i} \prod_{j=1}^r \left(\frac{x_j}{n_j} \right)^i \left(\frac{n_j - x_j}{n_j} \right)^{N-i}.$$

However, when some $x_j = 0$, we are unwilling to estimate that

the probability of at least a > 0 accidents in N future trials is zero (or even that the expected number of future accidents in N trials is zero). We shall give, in the following paragraphs, a reasonable nonzero estimate of this probability.

Let n be the number of times an accident could have occurred (i.e., the exposure). Clearly, we have $n \leq \min(n_1, \dots, n_r)$. If we know n , we shall use it in the following calculations; otherwise we shall use $n^* = \min(n_1, \dots, n_r)$. Use of n^* is conservative in the sense that we shall assume that we have observed no accidents in n^* (which is at least as large as n and very likely much larger) trials, and based on this more improbable event wish to estimate the probability of at least a > 0 accidents in N future trials.

We know that $\Pr\{X = 0 \mid \theta, n\} = (1 - \theta)^n$. This function, which arises naturally here, seems like a reasonable weight function for θ , in the sense that $\theta = 0$ gets weight 1 and as θ increases to 1 the weight of θ decreases monotonically to 0; and this is the proper behavior of a function that weights the probability of a given θ when we know that $X = 0$ in n trials. To get a "probability distribution" of θ , we multiply $(1 - \theta)^n$ by $(n + 1)$, since $(n + 1) \int_0^1 (1 - \theta)^n d\theta = 1$.

It is interesting to note that this probability distribution is the a posteriori distribution of θ , given zero accidents in n trials and given that θ has an a priori uniform distribution. The way in which the frequency of θ under this

beta distribution, $f(\theta | n) = (n + 1)(1 - \theta)^n$, declines with increasing values of θ is shown in the following table for different values of n (number of past exposures).

FREQUENCY OF θ UNDER BETA DISTRIBUTION

θ	$f(\theta n=100)$	$f(\theta n=1000)$	θ	$f(\theta n=10,000)$
0	101.00	1,001.00	0	10,001.00
0.001	91.38	368.06	0.0001	3,678.94
0.002	82.68	135.20	0.0002	1,353.20
0.004	67.65	18.19	0.0004	183.03
0.006	55.33	2.44	0.0006	24.74
0.008	45.24	0.33	0.0008	3.34
0.010	36.97	0.043	0.0010	0.45
0.012	30.20	0.0057	0.0012	0.061
0.014	24.66	0.0007	0.0014	0.0082
...	0.0016	0.0011
0.02	13.39	0.0000	0.0018	0.0001
0.04	1.70	0.0000		
0.10	0.0027	0.0000		

Now we have

$$\Pr\{X \geq a | \theta, N\} = \sum_{x=a}^N \binom{N}{x} \theta^x (1 - \theta)^{N-x} = f_a(N, \theta).$$

The value θ is unknown, but we have a "probability distribution" of θ and we might, then, get the "average" $f_a(N, \theta)$ (with respect to this probability distribution), namely

$$\begin{aligned} g_a(N, n) &= (n+1) \int_0^1 \sum_{x=a}^N \binom{N}{x} \theta^x (1-\theta)^{N-x} (1-\theta)^n d\theta \\ &= (n+1) \sum_{x=a}^N \binom{N}{x} \frac{\Gamma(x+1) \Gamma(N+n-x+1)}{(N+n+2)!} \\ &= \frac{(n+1)N!}{(N+n+1)!} \sum_{x=a}^N \frac{(N+n-x)!}{(N-x)!} \frac{n!}{n!} \end{aligned}$$

$$\begin{aligned}
&= \binom{N+n+1}{N}^{-1} \left\{ \sum_{x=0}^N \binom{N+n-x}{n} - \sum_{x=0}^{a-1} \binom{N+n-x}{n} \right\} \\
&= \binom{N-n+1}{N}^{-1} \left\{ \sum_{x=a}^{N+n-1} \binom{N+n-x}{n} - \sum_{x=N+1}^{N+n-1} \binom{N+n-x}{n} \right\}.
\end{aligned}$$

Letting

$$\begin{aligned}
v &= x - a, & w &= x - N - 1, \\
\alpha &= N + n - a, & \beta &= n - 1,
\end{aligned}$$

we obtain

$$\begin{aligned}
g_a(N, n) &= \binom{N-n+1}{N}^{-1} \left\{ \sum_{v=0}^{\alpha-1} \binom{\alpha-v}{n} - \sum_{w=0}^{\beta-1} \binom{\beta-w}{n} \right\} \\
&= \binom{N-n+1}{N}^{-1} \left\{ \binom{\alpha+1}{n+1} - \binom{\beta+1}{n+1} \right\}
\end{aligned}$$

by 9.14 of [3], whence

$$g_a(N, n) = \frac{\binom{N+n-a+1}{n+1}}{\binom{N+n+1}{N}}$$

since

$$\binom{\beta+1}{n+1} = \binom{n}{n+1} = 0,$$

and therefore

$$g_a(N, n) = \frac{(N + n - a + 1)! N!}{(N + n + 1)! (N - a)!}.$$

The "average" probability of at least one accident in N future trials, given that we observed zero accidents in n trials, is, then,

$$g_1(N, n) = \frac{N}{N + n + 1}.$$

To obtain the expected number of accidents in N future trials, we first obtain the "average probability" that $X = a$, given θ and N , which is

$$g_a(N, n) - g_{a+1}(N, n) = g'_a(N, n) = \frac{N!(N + n - a)!(n + 1)}{(N + n + 1)!(N - a)!}.$$

The expectation, then, is

$$\begin{aligned} \sum_{a=0}^N a g'_a(N, n) &= \frac{N!(n + 1)!}{(N + n + 1)!} \sum_{a=0}^N a \binom{N+n-a}{n} \\ &= \binom{N+n+1}{N}^{-1} \left\{ \sum_{a=0}^{\alpha-1} a \binom{\alpha-a}{n} - \sum_{b=0}^{\beta-1} (b + N + 1) \binom{\beta-b}{n} \right\}, \end{aligned}$$

where $\alpha = N + n$, $b = a - N - 1$, $\beta = n - 1$. But

$$\sum_{a=0}^{\alpha-1} a \binom{\alpha-a}{n} = \binom{\alpha+1}{n+2},$$

(this can be shown by induction on $\alpha \geq n > 0$), so that

$$\begin{aligned} \sum_{a=0}^N a g'_a(N, n) &= \binom{N+n+1}{N}^{-1} \left\{ \binom{\alpha+1}{n+2} - \binom{\beta+1}{n+2} - (N + 1) \binom{\beta+1}{n+1} \right\} \\ &= \frac{\binom{N+n+1}{n+2}}{\binom{N+n+1}{N}} = \frac{N}{n + 2}, \end{aligned}$$

or N times the Bayes estimate of θ given that $x = 0$.

One should of course note the inconsistency in our estimation procedure. If $x_j \neq 0$ for all j , we use the maximum likelihood estimate of the expected number of accidents in N future trials; if some $x_j = 0$, we use a Bayesian estimate of this expected number. The only justification of this that we can give is that in our context a conservative estimate of θ (i.e., one whose expectation is greater than θ) is perhaps more satisfactory than an unbiased estimate.

4. TOLERANCE LIMITS AND CONFIDENCE LIMITS

There are two problems that will be considered here: (1) How sure can one be that in N future trials the probability is greater than π (say 0.95) that there will be less than 1 accident, given $\hat{\theta}$? (2) At most, how many accidents can one be 100 γ per cent (say 99 per cent) sure of having in N future trials, given $\hat{\theta}$?

The first problem is one of finding the probability, γ^* , that an upper tolerance limit for the binomial distribution including 100 π per cent of the population lies below 1. The second problem is one of finding an upper 100 γ per cent confidence limit on $N\theta$, or equivalently on θ .

4.1. Tolerance Limits

Let

$$\gamma^* = \Pr\{B^*(1 | \hat{\theta}, N) \leq 1 - \pi | \theta, \{n\}\} ,$$

where $B^*(1 | \hat{\theta}, N) = \Pr\{X \geq 1 | \hat{\theta}, N\}$, where X has a binomial distribution with parameters $\hat{\theta}$ and N , where θ is the true probability of an accident, and where $\{n\}$ is the set of sample sizes n_1, \dots, n_r . Then

$$\begin{aligned}\gamma^* &= \Pr\{1 - B^*(1 | \hat{\theta}, N) \geq \pi | \theta, \{n\}\} \\ &= \Pr\{(1 - \hat{\theta})^N \geq \pi | \theta, \{n\}\} \\ &= \Pr\{\hat{\theta} \leq 1 - \pi^{1/N} | \theta, \{n\}\} \\ &= \Pr\left\{\prod_{j=1}^r x_j \leq C_{N\pi} \prod_{j=1}^r n_j | \theta, \{n\}\right\},\end{aligned}$$

where $C_{N\pi} = 1 - \pi^{1/N}$. But

$$E \prod_{j=1}^r x_j = \prod_{j=1}^r n_j \theta_j$$

and

$$\text{Var} \prod_{j=1}^r x_j = \prod_{j=1}^r n_j \theta_j (1 - \theta_j).$$

If θ_j were relatively large for each j , then using the normal approximation to the binomial we would have

$$\hat{\gamma}_1^* \approx \Phi\left(\frac{C_{N\pi} \prod_{j=1}^r n_j - \prod_{j=1}^r n_j \hat{\theta}_j}{\sqrt{\prod_{j=1}^r n_j \hat{\theta}_j (1 - \hat{\theta}_j)}}\right)$$

as an estimate of γ^* , where

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^x e^{-t^2/2} dt.$$

However, since θ_j is small relative to n_j , we have

$$\text{Var } \prod_{j=1}^r x_j \approx \prod_{j=1}^r n_j \theta_j = E \prod_{j=1}^r x_j,$$

and we might approximate $\prod_{j=1}^r x_j$ with a Poisson distribution with parameter $\lambda = \prod_{j=1}^r n_j \theta_j$, and might estimate γ^* by

$$\hat{\gamma}_2^* = P\left(C_{N\pi} \prod_{j=1}^r n_j \mid \hat{\lambda} = \prod_{j=1}^r n_j \hat{\theta}_j\right),$$

where $P(x \mid \lambda)$ is the area below x of the tail of the Poisson distribution with parameter λ .

For example, let $r = 2$, $\hat{\lambda} = 1$, $\pi = 0.95$, $n_1 = n_2 = 100$, and $N = 1000$. Then $C_{N\pi} \prod_{j=1}^2 n_j \approx 10^{-5} \times 10^4 = 10^{-1}$, and $\hat{\gamma}_2^* = P(0.1 \mid 1) = 0.368$. That is, if one makes the statement that "with a high degree of confidence" (95 per cent) there will be no accidents in the next 1000 trials based on past experience, then 0.368 may be called a measure of the "good reasons" one has in making this statement; i.e., in this case one really does not believe very strongly that one can have such a high statistical confidence in expecting zero accidents.

4.2. Confidence Limits

Finding an upper 100 γ per cent confidence limit on θ , given that we observe the r events the intersection of which makes up the accident rather than accidents themselves, is a difficult task. If we were observing accidents only and observed t accidents in n trials, we would use the θ_U that is the value of θ for which

$$\sum_{i=0}^t \binom{n}{i} \theta^i (1 - \theta)^{n-i} = 1 - \gamma$$

as the upper 100γ per cent confidence limits on θ . Tables of these confidence limits are given in [2].

Since we observe only the events that make up an accident, paying no heed as to whether they have or have not occurred simultaneously, we have the problem of finding a

$C_{n_1, \dots, n_r}(x_1, \dots, x_r; \gamma)$ such that $\Pr\{0 \leq \theta \leq C_{n_1, \dots, n_r}(x_1, \dots, x_r; \gamma)\} = \gamma$ (or $\geq \gamma$ if we wish to be a bit less precise but fully as conservative in our requirement for an upper confidence limit). Buehler [2] gives upper confidence limits for $\theta \prod_{j=1}^r n_j$ when $r = 2$. To get upper confidence limits for $N\theta$, we need only multiply his tabulated value by $N/(n_1 n_2)$. The Buehler technique can easily be generalized and tables for any value of r can be computed with increasing difficulty as r increases. His technique is, however, arbitrary and has no so-called "optimal" properties.

Another way of looking at the "confidence interval" problem suggested by L. J. Savage is to use the likelihood ratio as an index of implausibility of a given θ . It is appealing in that it deals directly with θ rather than with the nuisance parameters $\theta_1, \dots, \theta_r$ with which Buehler is concerned. The likelihood ratio \mathcal{L}_0 is, in our case, using the Poisson approximation,

$$\mathcal{L}_0 = \sum_{j=1}^r x_j (\ln \lambda_j - \ln x_j) - \sum_{j=1}^r (\lambda_j - x_j).$$

Values of λ for which \mathcal{L}_0 is as little as $-2r$ (or $-3r$) can be regarded as strongly contraindicated. One reason for this is based on an asymptotic argument. In this context, $-2\mathcal{L}_0$ has an asymptotic χ^2 distribution with r degrees of freedom; thus

$$\Pr\{\mathcal{L}_0 < -2r\} = \Pr\{-2\mathcal{L}_0 > 4r\} = \Pr\{\chi^2(r) > 4r\} = f(r).$$

Various values of r and $f(r)$ are tabulated below:

r	$f(r)$
1	0.042
2	0.019
3	0.008
4	0.004
5	0.001

It is instructive to see how large \mathcal{L}_0 can be for a given value of

$$\phi = \prod_{i=1}^r \lambda_i = \theta \prod_{i=1}^r n_i.$$

According to the Lagrange-multiplier method, we study

$$\begin{aligned} 0 &= \frac{\partial}{\partial \lambda_j} \left\{ \mathcal{L}_0 - t \ln \phi \right\} \\ &= \frac{x_j}{\lambda_j} - 1 - \frac{t}{\lambda_j}, \end{aligned}$$

or $\lambda_j = x_j - t$. As the Lagrange parameter t ranges down from

the smallest x_j to $-\infty$, ϕ ranges from 0 to ∞ . In terms of this t , $\hat{\mathcal{L}}_0$, the maximized \mathcal{L}_0 , is

$$\hat{\mathcal{L}}_0 = \sum_{j=1}^r x_j \ln \left(1 - \frac{t}{x_j} \right) + rt.$$

To interpret $\hat{\mathcal{L}}_0$, one could say that it points "seriously" away from a value of the parameter of interest only if $\hat{\mathcal{L}}_0 < -2$ or -5 , depending on what is meant by "serious."* The shred of evidence for this contention will be given later.

Let us determine $\hat{\mathcal{L}}_0$ in terms of ϕ for a specific case. Let $r = 3$, $x_1 = x_2 = x_3 = 1$. Then

$$\begin{aligned} \lambda_j &= (1 - t); \\ \phi &= \prod_{j=1}^3 \lambda_j = (1 - t)^3; \\ t &= 1 - \phi^{1/3}; \\ \hat{\mathcal{L}}_0 &= 3 \{ \ln (1 - t) + t \} \\ &= 3 \{ \ln \phi^{1/3} + (1 - \phi^{1/3}) \} \\ &= \ln \phi + 3(1 - \phi^{1/3}), \quad -\infty < t < 1. \end{aligned}$$

Various values of ϕ and $\hat{\mathcal{L}}_0$ are tabulated below:

*This interpretation is due to L. J. Savage.

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ϕ	$\hat{\mathcal{L}}_0$
1/64	-2
1/27	-1.3
1/8	-0.58
1	0
8	-0.92
27	-2.7
64	-4.85

Still worse, when $r = 6$, $x_j = 1$ for all j , we have

$$\hat{\mathcal{L}}_0 = \ln \phi + 6(1 - \phi^{1/6}),$$

which gives the following values:

ϕ	$\hat{\mathcal{L}}_0$
1/64	-1.25
1	0
64	-1.75

Accordingly, using this as our criterion for unlikeliness of a particular value of ϕ , we see that the sample gives little evidence about ϕ and the evidence gets worse as we increase r (i.e., break down the accident into more and more independent events that must occur simultaneously to produce an accident and that we will observe separately).

One may think of improving these "confidence limits" by making r smaller, that is, by breaking the event of a full accident into a smaller number of combined events. However, if one does this, usually fewer observations on actual exposures

are available. For example, if event $r - 1$ is technical failure of safety switch A, and event r is accidental release of the bomb through human error, then reducing r to $r - 1$ would introduce a new, larger event, namely the combination of the two, on which fewer past exposures could be observed. (One can check the correct functioning of switch A on a great many weapons, but one can check it only on a few accidentally dropped weapons.) Thus, the number of past exposures of the larger, combined event is usually smaller than the number of exposures of the constituent events. Yet, this does not mean that we would not gain by reducing r , at the expense of also reducing n_j .

Let us once again consider the example when $r = 3$, $x_1 = x_2 = x_3 = 1$. Let $n_j = n$ for all j . Then

$$\hat{\mathcal{L}}_0 = \ln \theta + 3 \ln n + 3(1 - n^3\theta)^{1/3}.$$

We shall look at $\hat{\mathcal{L}}_0$ for various values of θ to determine $n(\theta)$, roughly, such that for a given θ , we have $\hat{\mathcal{L}}_0 < -2$ for this $n(\theta)$. We obtain the following values:

θ	$n(\theta)$	$\hat{\mathcal{L}}_0$
0.00005	40	-2.8
0.00055	20	-2.7
0.00499	10	-3.2

This means that for values of $n(\theta)$ larger than those tabled we are more certainly going to be led to conclude that the

corresponding θ is unlikely when $x_1 = x_2 = x_3 = 1$. Since our sample sizes, though they will be decreased by a reduction in r , will not be as small as the $n(\theta)$'s tabulated above, we feel that the reduction in n is of little consequence here.

One final point must be checked. To make the Poisson approximation, $\lambda_j = n_j \theta_j$ must be very small compared to n_j . A traditional view is that $n_j \geq 6$ and $\theta_j \leq 0.125$ is good enough for the approximation. Since we used the Poisson approximation in our last calculation, merely substituting $n_j \theta_j$ for λ_j in the expression for $\hat{\mathcal{L}}_0$ based on the Poisson distribution, we should check to see whether we exceeded the bounds of the approximation in doing so. Our $n(\theta)$'s, as tabled above, satisfy the condition on n_j , and θ is small enough so that all the θ_j 's involved should be for the most part less than 0.125 (though this is obviously not necessarily true).

Using the likelihood-ratio approach, we have not given an explicit formula or table for obtaining confidence limits for θ . We have, however, presented a procedure by which one can assess the "likelihood" of a given θ from the observed sample. The following example gives an indication of what the value of $\hat{\mathcal{L}}_0$ may signify.

Let X_1, \dots, X_r be independent and normal random variables with unit variance and means u_1, \dots, u_r , and let

$$\gamma = \sum_{j=1}^r f_j u_j,$$

where the f_j are constants. It would be universally accepted as good statistical practice to base all decisions about γ on the quantity

$$C = \sum_{j=1}^r f_j X_j,$$

which is normally distributed about γ with variance

$$\sigma^2 = \sum_{j=1}^r f_j^2.$$

Values of γ outside $C \pm 2\sigma$ would be rather discredited, values outside $C \pm 3\sigma$ would be highly discredited, and values outside $C \pm 4\sigma$ would be beyond all ordinary consideration. What does the $\hat{\mathcal{L}}_0$ -approach lead to here, where an answer is already known or at least accepted? We have

$$\mathcal{L}_0 = -\frac{1}{2} \sum_{j=1}^r (x_j - u_j)^2,$$

$$\frac{\partial \mathcal{L}_0 - t\gamma}{\partial u_j} = (x_j - u_j) - tf_j = 0,$$

$$u_j = x_j - tf_j,$$

$$\begin{aligned} \gamma &= \sum_{j=1}^r f_j u_j = \sum_{j=1}^r f_j x_j - t \sum_{j=1}^r f_j^2 \\ &= C - t\sigma^2, \end{aligned}$$

$$t = (C - \gamma)/\sigma^2,$$

$$\begin{aligned}\hat{\chi}_0^2 &= \frac{1}{2} \sum_{j=1}^r \left[x_j - \left(x_j - \frac{c - \gamma}{\sigma^2} f_j \right) \right]^2 \\ &= \frac{1}{2} \sum_{j=1}^r \frac{(c - \gamma)^2}{\sigma^4} f_j^2 = \frac{1}{2} \left| \frac{c - \gamma}{\sigma} \right|^2.\end{aligned}$$

Thus $\hat{\chi}_0^2$ is determined by just that ratio that traditionally has been taken as the gauge of significance in this problem. Values beyond $\pm 2\sigma$, $\pm 3\sigma$, and $\pm 4\sigma$ correspond to $\hat{\chi}_0^2 < -2$, -4.5 , and -8 .

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